NNG06ED46C

LRO S-Band TT&C Subsystem

CONTRACT

(5|23|06)

SCAN

OMB APPROVAL #: 2700-0042

AWARD/CONTRACT	1. THIS CONTRACT IS A RATED ORDER UNDER DPAS (15 CFR 350) ⇒	RATING	PAGE OF PAGES 1 34
2. CONTRACT NO. (*Proc. Inst. Ident.*) NO. NNG06ED46C	3. EFFECTIVE DATE MAY 23 2006	4. REQUISITION/PURCHASE REQUEST/PROJECT NO. 4200138273	

5. ISSUED BY: CODE 210.S	6. ADMINISTERED BY (*If other than item 5*) CODE 460
NASA Goddard Space Flight Center Greenbelt, Maryland 20771	Julie Janus (301) 286-4931

7. NAME AND ADDRESS OF CONTRACTOR (No., street, city, county, State and ZIP	CODE ONWP5	FACILITY CODE
General Dynamics C4 System 8201 E. McDowell Road Scottsdale, Arizona 85252-1417		

8. DELIVERY ☐ FOB ORIGIN ☒ OTHER	9. DISCOUNT FOR PROMPT N/A
10. SUBMIT INVOICES (*4 copies unless other-wise specified*) TO THE ADDRESS SHOWN IN: ⇒	ITEM Clause G.2

11. SHIP TO/MARK FOR CODE 155	12. PAYMENT WILL BE MADE BY: CODE 155
NASA Goddard Space Flight Center Cost and Commercial Accounts Department Greenbelt, Maryland 20771	NASA Goddard Space Flight Center Cost and Commercial Accounts Department Greenbelt, Maryland 20771

13. AUTHORITY FOR USING OTHER THAN FULL AND OPEN N/A	14. ACCOUNTING AND APPROPRIATION DATA
☐ 10 U.S.C. 2304(c) ☐ 41 U.S.C. 253(c)	4200138273; 6100.2550; 51; 2550; 342556.06.01.10.02; FC300205; 515670; 51-342556: ESAX22006D: $2.399.312: B/NC: GCE: PPC: BX

15A. ITEM NO.	15B. SUPPLIES/SERVICES	15C. QTY	15D. UNIT	15E. UNIT PRICE	15F. AMOUNT
	LRO S-Band TT&C Subsystem				
				15G. TOTAL AMOUNT OF CONTRACT ⇒	**$4,798,623**

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CONTRACTING OFFICER WILL COMPLETE ITEM 17 OR 18 AS APPLICABLE

17 ☒ CONTRACTOR'S NEGOTIATED AGREEMENT (*Contractor is required to sign this document and return* 4 *copies to issuing office.*) Contractor agrees to furnish and deliver all items or perform all the services set forth or otherwise identified above and on any continuation sheets for the consideration stated herein. The rights and obligations of the parties to this contract shall be subject to and governed by the following documents (s) this award/contract, (b) the solicitation, if any, and (c) such provisions, representations, certifications, and specifications, as are attached or incorporated by reference herein. (*Attachments are listed herein.*)

18. ☐ AWARD (*Contractor is not required to sign this document.*) Your offer on Solicitation Number _____, including the additions or changes made by you which additions or changes are set forth in full above, is hereby accepted as to the items listed above and on any continuation sheets. This award consummates the contract which consists of the following documents: (a) the Government's solicitation and your offer, and (b) this award/contract. No further contractual document is necessary.

19A. NAME AND TITLE OF SIGNER (*Type or print*)	20A. NAME OF CONTRACTING OFFICER
Ron Taylor, Vice President & General Manager	Julie Janus, Contracting Officer

19B. NAME OF CONTRACTOR	19C. DATE SIGNED	20B. UNITED STATES OF AMERICA	20C. DATE SIGNED
BY _____ (*Signature of person authorized to sign*)	5/23/06	BY _____ (*Signature of Contracting Officer*)	MAY 23 2006

NSN 7540-01-152-8070
PREVIOUS EDITION UNUSABLE

JSC Word 6 Form (8-95)

STANDARD FORM 26 (REV. 4-85)
Prescribed By GSA

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INDEX OF CLAUSES FOR NNG06ED46C

INDEX OF CLAUSES FOR NNG06ED46C

SECTION H--SPECIAL CONTRACT REQUIREMENTS

SECTION I--CONTRACT CLAUSES

SECTION J--LIST OF ATTACHMENTS

SECTION B OF NNG06ED46C
SUPPLIES OR SERVICES AND PRICES/COSTS

B.1 DELIVERABLE REQUIREMENTS (GSFC 52.211-90) (OCT 1988)

The Contractor shall perform and/or deliver the following:

Item #	Description	Reference	Quantity	Delivery Date
1	SOW Requirements (431-SOW-000303)	C.1 & J.1	See C.1 & J.1	See C.1& J.1
2	Performance Specification (431-SPEC-000121)	C.1 & J.1	See C.1 & J.1	See C.1& J.1
3	Deliverable Items List and Schedule (431-LIST-000304)	C.1 & J.1	See C.1 & J.1	See C.1 & J.1
4	DoD Industrial Plant Equipment (Form DD 1419)	NFS 1852.245-70	See G.1	See G.1
5	NASA Property in the Custody of Contractors (NASA Form 1018)	NFS 1852.245-73	See I.1	See I.1
6	New Technology Reports	G.1	See G.1	See G.1
7	Monthly Progress Reports	C.3	See C. 3	See C. 3
8	Final Report	C.2	1H/1E	Sixteen (16) months after contract award (ACA) plus thirty (30) days
9	Small Business Subcontracting Reports	H.3 & I.1	See H.3 & I.1	See H.3 & I.1
10	Commercial Transportation Bills	I.1	See FAR 52.247-67	See FAR 52.247-67
11	Protoflight S-Band TT&C Subsystem	SOW Section 5.6	1	Thirteen and One-Half (13.5) months ACA
12	Flight Qualified S-Band TT&C Subsystem	SOW Section 5.6	1	Sixteen (16) months ACA

SECTION B OF NNG06ED46C
SUPPLIES OR SERVICES AND PRICES/COSTS

Item #	Description	Reference	Quantity	Delivery Date
13	Connector Savers	SOW Section 5.7	1 for every external connector	with Item #11 and #12
14	Mating Connectors	SOW Section 5.8	1 set of external connectors per TT&C Subsystem, plus two additional sets per TT&C Subsystem (Total of 6 sets)	with Item #11 and #12
15	Electrostatic Discharge (ESD) Caps	SOW Section 5.8	1 for every external connector; 1 closeout cap for every test connector	with Item #11 and #12
16	Shipping Containers	SOW Section 5.8	1 for each S-Band Transponder	with Item #11 and #12
17	Drill Template	SOW Section 5.8	1	At CDR
18	Transponder Test Controller	SOW Section 5.9	1	With Item #11

(End of text)

B.2 FIRM FIXED PRICE (1852.216-78) (DEC 1988)

The total firm fixed price of this contract is $4,798,623.

(End of clause)

SECTION B OF NNG06ED46C
SUPPLIES OR SERVICES AND PRICES/COSTS

B.3 MILESTONE PAYMENT SCHEDULE (For Offeror Fill-In)

(a) Subject to other limitations and conditions specified in this contract, milestone payment shall be made to the Contractor upon delivery and acceptance of the milestone events described under paragraph (b).

(b) The payment schedule amount shall be calculated by the application of the contract percentage established per milestone event to the to the total fixed price amount indicated under contract clause B.2, entitled "Firm-Fixed Price".

MILESTONE EVENT	QTY	CONTRACT PERCENTAGE	Unit Price	TOTAL AMOUNT
Monthly Status Reports	16	10%	$29,991	$479,856
Preliminary Design Review Report	1	10%	$479,868	$479,868
Interface Control Documents	1	5%	$239,931	$239,931
Critical Design Review Report	1	10%	$479,862	$479,862
Pre Shipment Review Data Package	2	5%	$119,965	$239,930
Prototype S-Band TT&C Subsystem (includes Test Controller)	1	20%	$959,726	$959,726
Flight Qualified S-Band TT&C Subsystem	1	30%	$1,439,587	$1,439,587
Final Report	1	10%	$479,863	$479,863
Grand Total	24	100%		$4,798,623

(c) The Contractor may submit requests for payment not more frequently than monthly, in a form and manner acceptable to the Contracting Officer. Unless otherwise authorized by the Contracting Officer, all milestone payments in any period for which payment is being requested shall be included in a single request, appropriately itemized and totaled.

(d) The Contractor shall not be entitled to payment of a request for milestones payment prior to successful accomplishment and acceptance by the Government of the milestone event. The Contracting Officer shall determine whether the milestone event or performance criterion for which payment is requested has been successfully accomplished and accepted by the Government in accordance with the terms of the contract. The Contracting Officer may, at any time, require the Contractor to substantiate the successful performance of any event or performance criterion which has been or is represented as being payable.

(End of Text)

SECTION C OF NNG06ED46C
DESCRIPTION/SPECIFICATIONS/WORK STATEMENT

C.1 SCOPE OF WORK (GSFC 52.211-91) (FEB 1991)

The Contractor shall provide the personnel, materials and facilities, except as otherwise provided in the contract, necessary to provide the items described below and as described under Section J, Attachment A, entitled "Lunar Reconnaissance Orbiter S-Band Telemetry, Tracking and Command Subsystem Statement of Work" dated February 8, 2006, Attachment B, entitled "Lunar Reconnaissance Orbiter S-Band Telemetry, Tracking and Command Subsystem Performance Specification" dated February 8, 2006, and Attachment C, entitled "Lunar Reconnaissance Orbiter S-Band Telemetry, Tracking and Command Subsystem Deliverable Items List and Schedule" dated February 8, 2006. In addition, the Contractor shall provide the items specified under contract clause B.1.

(End of clause)

C.2 FINAL SCIENTIFIC AND TECHNICAL REPORTS (1852.235-73)(JAN 2005)

(a) The Contractor shall submit to the Contracting Officer a final report that summarizes the results of the entire contract, including recommendations and conclusions based on the experience and results obtained. The final report should include tables, graphs, diagrams, curves, sketches, photographs, and drawings in sufficient detail to explain comprehensively the results achieved under the contract.

(b) The final report shall be of a quality suitable for publication and shall follow the formatting and stylistic guidelines contained in NPR 2200.2A, Guidelines for Documentation, Approval, and Dissemination of NASA Scientific and Technical Information. Electronic formats for submission of reports should be used to the maximum extent practical. Before electronically submitting reports containing scientific and technical information (STI) that is export-controlled or limited or restricted, contact the Contracting Officer to determine the requirements to electronically transmit these forms of STI. If appropriate electronic safeguards are not available at the time of submission, a paper copy or a CD-ROM of the report shall be required. Information regarding appropriate electronic formats for final reports is available at http://www.sti.nasa.gov under "Publish STI – Electronic File Formats."

(c) The last page of the final report shall be a completed Standard Form (SF) 298, Report

Documentation Page.

(d) In addition to the final report submitted to the Contracting Officer, the Contractor shall concurrently provide to the Center STI/Publication Manager and the NASA Center for AeroSpace Information (CASI) a copy of the letter transmitting the final report to the Contracting Officer. The copy of the letter shall be submitted to CASI at the following address:

Center for AeroSpace Information (CASI)
Attn: Acquisitions Collections Development Specialist

7121 Standard Drive
Hanover, Maryland 21076-1320

(e) In accordance with paragraph (d) of the Rights in Data --General clause (52.227-14) of this contract, the Contractor may publish, or otherwise disseminate, data produced during the performance of this contract, including data contained in the final report, and any additional reports required by 1852.235-74 when included in the contract, without prior review by NASA. The Contractor is responsible for reviewing publication or dissemination of the data for conformance with laws and regulations governing its distribution, including intellectual property rights, export control, national security and other requirements, and to the extent the contractor receives or is given access to data necessary for the performance of the contract which contain restrictive markings, for complying with such restrictive markings. Should the Contractor seek to publish or otherwise disseminate the final report, or any additional reports required by 1852.235-74 if applicable, as delivered to NASA under this contract, the Contractor may do so once NASA has completed its document availability authorization review, and availability of the report has been determined.

(End of clause)

C.3 ADDITIONAL REPORTS OF WORK--RESEARCH AND DEVELOPMENT (1852.235-74) (FEB 2003)

In addition to the final report required under this contract, the Contractor shall submit the following report(s) to the Contracting Officer:

(a) Monthly progress reports. The Contractor shall submit separate monthly reports of all work accomplished during each month of contract performance. Reports shall be in narrative form, brief, and informal. They shall include a quantitative description of progress, an indication of any current problems that may impede performance, proposed corrective action, and a discussion of the work to be performed during the next monthly reporting period.

(b) RESERVED

(c) Submission dates. Monthly reports shall be submitted by the 15th day of the month following the month being reported. If the contract is awarded beyond the middle of a month, the first monthly report shall cover the period from award until the end of the following month. No monthly report need be submitted for the final month of contract effort since that period will be covered in the final report. The final report shall be submitted within 30 days after the completion of the effort under the contract.

(End of clause)

SECTION D OF NNG06ED46C
PACKAGING AND MARKING

D.1 PACKAGING, HANDLING, AND TRANSPORTATION (1852.211-70) (NOV 2004)

(a) The Contractor shall comply with NPR 6000.1E, "Requirements for Packaging, Handling, and Transportation for Aeronautical and Space Systems, Equipment, and Associated Components", dated April 26, 1999, as may be supplemented by the statement of work or specifications of this contract, for all items designated as Class I, II, or III.
(b) The Contractor's packaging, handling, and transportation procedures may be used, in whole or in part, subject to the written approval of the Contracting Officer, provided (1) the Contractor's procedures are not in conflict with any requirements of this contract, and (2) the requirements of this contract shall take precedence in the event of any conflict with the Contractor's procedures.
(c) The Contractor must place the requirements of this clause in all subcontracts for items that will become components of deliverable Class I, II, or III items.

(End of clause)

SECTION E OF NNG06ED46C
INSPECTION AND ACCEPTANCE

E.1 SECTION E-CLAUSES INCORPORATED BY REFERENCE

(52.246-7) INSPECTION OF RESEARCH AND DEVELOPMENT – FIXED PRICE (AUG 1996)

(52.246-16) RESPONSIBILITY FOR SUPPLIES (APR 1984)

E.2 MATERIAL INSPECTION AND RECEIVING REPORT (1852.246-72) (AUG 2003)

(a) At the time of each delivery to the Government under this contract, the Contractor shall furnish a Material Inspection and Receiving Report (DD Form 250 series) prepared in an original copy and sufficient other copies to accomplish the following distribution:

(1) Via mail and marked "Advance Copy", one copy each to the Contracting Officer, the Contracting Officer's Technical Representative (if designated in the contract), and to the cognizant Administrative Contracting Officer, if any.

(2) Via mail, the original and 1 copy (unfolded) to the shipment address (delivery point) specified in Section F of this contract. Mark the exterior of the envelope "CONTAINS DD FORM 250". This must arrive prior to the shipment.

(3) With shipment in waterproof envelope (one copy) for the consignee.

(4) If the shipment address is not directly to the Goddard Space Flight Center (Greenbelt) or Goddard Space Flight Center (Wallops) central receiving areas, then one copy of the DD Form 250 must be provided (via mail) to one on the following addresses depending upon whether this contract is with GSFC Greenbelt or GSFC Wallops:

Receiving and Inspection (Code 239), Goddard Space Flight Center, Greenbelt, MD 20771.

Receiving and Inspection (Bldg. F16), Wallops Flight Facility, Wallops Island VA 23337.

(b) The Contractor shall prepare the DD Form 250 in accordance with NASA FAR Supplement 18-46.6. The Contractor shall enclose the copies of the DD Form 250 in the package or seal them in a waterproof envelope, which shall be securely attached to the exterior of the package in the most protected location.

(c) When more than one package is involved in a shipment, the Contractor shall list on the DD Form 250, as additional information, the quantity of packages and the package numbers. The Contractor shall forward the DD Form 250 with the lowest numbered package of the shipment and print the words "CONTAINS DD FORM 250" on the package.

(End of clause)

E.3 ACCEPTANCE--SINGLE LOCATION (GSFC 52.246-92) (SEPT 1989)

SECTION E OF NNG06ED46C
INSPECTION AND ACCEPTANCE

The Contracting Officer or authorized representative will accomplish acceptance at GSFC. For the purpose of this clause, the Contracting Officer's Technical Representative named in this contract is the authorized representative.. The Contracting Officer reserves the right to unilaterally designate a different Government agent as the authorized representative. The Contractor will be notified by a written notice or by a copy of the delegation of authority if different representative is designated.

Acceptance shall be deemed to have occurred constructively--for the sole purpose of computing an interest penalty that might be due the Contractor under the Prompt Payment Act--on the Twentieth day after the Contractor has delivered the supplies or services in accordance with the terms and conditions of the contract. In the event that actual acceptance occurs within the constructive acceptance period, the determination of an interest penalty shall be based on the date of the actual acceptance.

(End of clause)

E.4 MATERIAL INSPECTION AND RECEIVING REPORT NOT REQUIRED (GSFC 52.246-94) (APR 1989)

NASA FAR Supplement clause 18-52.246-72 of this contract requires the furnishing of a Material Inspection and Receiving Report (MIRR) (DD Form 250 series) at the time of each delivery under this contract. However, a MIRR is not required for the following deliverable items:

All deliverable items contained in Clause B.1 except Items 11- 18.

(End of clause)

E.5 INSPECTION SYSTEM (SUBCONTRACTS) (GSFC 52.246-100) (JULY 2000)

In performance of this contract, the Contractor shall impose inspection system requirements on subcontractors and suppliers to ensure the required quality of supplies or services. Monitoring of the Contractor's system for inspecting subcontractors will be accomplished through the combined efforts of NASA/GSFC personnel and the delegated Government agency. The authority and responsibility of the delegated agency will be defined in a letter of contract administration delegation.

(End of clause)

E.6 INSPECTION SYSTEM RECORDS (GSFC 52.246-102) (OCT 1988)

The Contractor shall maintain records evidencing inspections in accordance with the Inspection clause of this contract for seven years after delivery of all items and/or completion of all services called for by the contract.

(End of clause)

SECTION E OF NNG06ED46C
INSPECTION AND ACCEPTANCE

E.7 GOVERNMENT CONTRACT QUALITY ASSURANCE FUNCTIONS (1852.246-71) (OCT 1988)

In accordance with the Inspection clause of this contract, the Government intends to perform the following functions at the locations indicated:

NO.	QUALITY ASSURANCE ITEM	QA FUNCTION	LOCATION
01	Testing	Monitoring and Witnessing by Government QA Representatives	Contractor and Subcontractor Facilities
02	Electronic Assemblies	Inspection of electronic assemblies prior to their installation	Contractor and Subcontractor Facilities
03	Mechanical Assemblies	Inspection of mechanical assemblies prior to assembly into next higher level of assembly	Contractor and Subcontractor Facilities
04	Manufacturing Process	Monitoring of various manufacturing processes for compliance	Contractor and Subcontractor Facilities
05	Procedural and Requirements Compliance	Surveys, audits, and monitoring of compliance to procedures and requirements	Contractor and Subcontractor Facilities

(End of clause)

SECTION F OF NNG06ED46C
DELIVERIES OR PERFORMANCE

F.1 *SECTION F-CLAUSE INCORPORATED BY REFERENCE*

(52.242-15) STOP-WORK ORDER (AUG 1989)
(52.247-34) F.O.B. DESTINATION (NOV 1991)

(End of clause)

F.2 SHIPPING INSTRUCTIONS--CENTRAL RECEIVING (GSFC 52.247-94) (JUL 1993)

Shipments of the items required under this contract shall be to:

Receiving Officer
Building 16W
Code 239
Goddard Space Flight Center
Greenbelt, Maryland 20771

Marked for:
Technical Officer: Jon Verville Code: 567
Building: 19 Room: S046
Contract No. NNG06ED46C

Compliance with this clause is necessary to assure verification of delivery and acceptance and prompt payment.

If this is a fixed price type contract, delivery--for purposes of the Prompt Payment Act--must be through the above shipping address unless another location has been authorized by the Contracting Officer. If delivery is made to other than Receiving, Building 16W, Code 239, and shipment to that other location has not been authorized by the Contracting Officer, a delivery for the purposes of the Prompt Payment Act has not occurred and no interest penalty under the Act shall result. Shipment to other than Receiving, Building 16W, Code 239, will be construed as contract noncompliance.

(End of clause)

F.3 ADVANCE NOTICE OF SHIPMENT (1852.247-72) (OCT 1988)

Ten (10) work days prior to shipping items identified below, the Contractor shall furnish the anticipated shipment date, bill of lading number (if applicable), and carrier identity to the Contracting Officer's Technical Representative and the Government's Quality Assurance Representative.

ITEM	DESCRIPTION	QTY	DELIVERY DATE	SHIPPING CLASS
11	Prototype S-Band TT&C Subsystem	1	Thirteen and One-Half (13.5) months after ACA	I

12	Flight Qualified S-Band TT&C Subsystem	1	Sixteen (16) months after ACA	I
13	Connector Savers	1 for every external connector	with Item #11 and #12	I
14	Mating Connectors	1 set of external connectors per TT&C Subsystem, plus two additional sets per TT&C Subsystem (Total of 6 sets)	with Item #11 and #12	I
15	Electrostatic Discharge (ESD) Caps	1 for every external connector; 1 closeout cap for every test connector	with Item #11 and #12	I
16	Shipping Containers	1 for each S-Band Transponder	with Item #11 and #12	I
17	Drill Template	1	At CDR	I
18	Transponder Test Controller	1	With Item #11	I

(End of clause)

SECTION G OF NNG06ED46C
CONTRACT ADMINISTRATION DATA

G.1 SECTION G-CLAUSES INCORPORATED BY REFERENCE

(1852.227-70) NEW TECHNOLOGY (MAY 2002)

(1852.245-70) CONTRACTOR REQUESTS FOR GOVERNMENT- OWNED EQUIPMENT (JUL 1997)

G.2 INVOICES - SUBMISSION OF (GSFC 52.232-95) (AUG 2000)

Invoices shall be prepared in accordance with the Prompt Payment clause of this contract and submitted to the Cost and Commercial Accounts Department, Code 155, NASA/Goddard Space Flight Center, Greenbelt, MD 20771. For purposes of the Prompt Payment Act, the above office is considered to be the "Designated Billing Office" and the "Designated Payment Office".

(End of clause)

G.3 DESIGNATION OF NEW TECHNOLOGY REPRESENTATIVE AND PATENT REPRESENTATIVE (1852.227-72) (JULY 1997)

(a) For purposes of administration of the clause of this contract entitled "New Technology" or "Patent Rights -- Retention by the Contractor (Short Form)", whichever is included, the following named representatives are hereby designated by the Contracting Officer to administer such clause:

Title	Office Code	Address (including zip code
New Technology	504	Goddard Space Flight Center Representative Greenbelt, MD 20771
Patent	503	Goddard Space Flight Center Representative Greenbelt, MD 20771

(b) Reports of reportable items, and disclosure of subject inventions, interim reports, final reports, utilization reports, and other reports required by the clause, as well as any correspondence with respect to such matters, should be directed to the New Technology Representative unless transmitted in response to correspondence or request from the Patent Representative. Inquiries or requests regarding disposition of rights, election of rights, or related matters should be directed to the Patent Representative. This clause shall be included in any subcontract hereunder requiring a "New Technology" clause or "Patent Rights--Retention by the Contractor (Short Form)" clause, unless otherwise authorized or directed by the Contracting Officer. The respective responsibilities and authorities of the above-named representatives are set forth in 1827.305-370 of the NASA FAR Supplement.

(End of clause)

G.4 RELEASE OF SENSITIVE INFORMATION (JUNE 2005) (1852.237-73)

(a) As used in this clause, "sensitive information" refers to information, not currently in the public domain, that the Contractor has developed at private expense, that may embody trade secrets or commercial or financial information, and that may be sensitive or privileged.
(b) In accomplishing management activities and administrative functions, NASA relies heavily on the support of various service providers. To support NASA activities and functions, these service providers, as well as their subcontractors and their individual employees, may need access to sensitive information submitted by the Contractor under this contract. By submitting this proposal or performing this contract, the Contractor agrees that NASA may release to its service providers, their subcontractors, and their individual employees, sensitive information submitted during the course of this procurement, subject to the enumerated protections mandated by the clause at 1852.237-72, Access to Sensitive Information.
(c)(1) The Contractor shall identify any sensitive information submitted in support of this proposal or in performing this contract. For purposes of identifying sensitive information, the Contractor may, in addition to any other notice or legend otherwise required, use a notice similar to the following:
Mark the title page with the following legend:
This proposal or document includes sensitive information that NASA shall not disclose outside the Agency and its service providers that support management activities and administrative functions. To gain access to this sensitive information, a service provider's contract must contain the clause at NFS 1852.237-72, Access to Sensitive Information. Consistent with this clause, the service provider shall not duplicate, use, or disclose the information in whole or in part for any purpose other than to perform the services specified in its contract. This restriction does not limit the Government's right to use this information if it is obtained from another source without restriction. The information subject to this restriction is contained in pages [insert page numbers or other identification of pages].
Mark each page of sensitive information the Contractor wishes to restrict with the following legend:
Use or disclosure of sensitive information contained on this page is subject to the restriction on the title page of this proposal or document.
(2) The Contracting Officer shall evaluate the facts supporting any claim that particular information is "sensitive." This evaluation shall consider the time and resources necessary to protect the information in accordance with the detailed safeguards mandated by the clause at 1852.237-72, Access to Sensitive Information. However, unless the Contracting Officer decides, with the advice of Center counsel, that reasonable grounds exist to challenge the Contractor's claim that particular information is sensitive,

NASA and its service providers and their employees shall comply with all of the safeguards contained in paragraph (d) of this clause.
(d) To receive access to sensitive information needed to assist NASA in accomplishing management activities and administrative functions, the service provider must be operating under a contract that contains the clause at 1852.237-72, Access to Sensitive Information. This clause obligates the service provider to do the following:
(1) Comply with all specified procedures and obligations, including the Organizational Conflicts of Interest Avoidance Plan, which the contract has incorporated as a compliance document.
(2) Utilize any sensitive information coming into its possession only for the purpose of performing the services specified in its contract.
(3) Safeguard sensitive information coming into its possession from unauthorized use and disclosure.
(4) Allow access to sensitive information only to those employees that need it to perform services under its contract.
(5) Preclude access and disclosure of sensitive information to persons and entities outside of the service provider's organization.
(6) Train employees who may require access to sensitive information about their obligations to utilize it only to perform the services specified in its contract and to safeguard it from unauthorized use and disclosure.
(7) Obtain a written affirmation from each employee that he/she has received and will comply with training on the authorized uses and mandatory protections of sensitive information needed in performing this contract.
(8) Administer a monitoring process to ensure that employees comply with all reasonable security procedures, report any breaches to the Contracting Officer, and implement any necessary corrective actions.
(e) When the service provider will have primary responsibility for operating an information technology system for NASA that contains sensitive information, the service provider's contract shall include the clause at 1852.204-76, Security Requirements for Unclassified Information Technology Resources. The Security Requirements clause requires the service provider to implement an Information Technology Security Plan to protect information processed, stored, or transmitted from unauthorized access, alteration, disclosure, or use. Service provider personnel requiring privileged access or limited privileged access to these information technology systems are subject to screening using the standard National Agency Check (NAC) forms appropriate to the level of risk for adverse impact to NASA missions. The Contracting Officer may allow the service provider to conduct its own screening, provided the service provider employs substantially equivalent screening procedures.
(f) This clause does not affect NASA's responsibilities under the Freedom of Information Act.
(g) The Contractor shall insert this clause, including this paragraph (g), suitably modified to reflect the relationship of the parties, in all subcontracts that may require the furnishing of sensitive information.

(End of clause)

SECTION H OF NNG06ED46C
SPECIAL CONTRACT REQUIREMENTS

H.1 SECTION H CLAUSES INCORPORATED BY REFERENCE

(1852.223-70)	SAFETY AND HEALTH (APR 2002)
(1852.223-75)	MAJOR BREACH OF SAFETY OR SECURITY (FEB 2002)
(1852.244-70)	GEOGRAPHIC PARTICIPATION IN THE AEROSPACE PROGRAM (APRIL 1985)

(End of By Reference Section)

H.2 REPRESENTATIONS, CERTIFICATIONS AND OTHER STATEMENTS OF OFFEROR (GSFC 52.215-90) (NOV 1999)

In accordance with FAR 15.204-1(b), the completed and submitted "Representations, Certifications, and Other Statements of Offeror", are incorporated by reference in this resulting contract.

(End of clause)

H.3 SMALL BUSINESS SUBCONTRACTING PLAN AND REPORTS (GSFC 52.219-90) (OCT 1999)

a. Subcontracting Plan (Contractor)

FAR clause 52.219-9, "Small Business Subcontracting Plan" is included in this contract. The agreed to Subcontracting Plan required by the clause is included as an attachment to the contract.

b. Subcontracting Plan (Subcontractors)

In accordance with FAR clause 52.219-9, the Contractor must require that certain subcontractors adopt a plan similar to the Plan agreed to between the Contractor and the Government.

c. Reporting to Contracting Officer (SF 294--Semi-annual and Final)

The Contractor shall prepare and submit Standard Form 294
(Rev. 12-98), "Subcontracting Report for Individual Contracts" in accordance with the instructions on the back of the form.

The SF 294 must be submitted to the Contracting Officer on a semi-annual basis. This report must be received no later than April 30 and October 30 each year for the reporting periods ending March 31 and September 30, respectively. A final SF 294 must be submitted after contract completion. The final SF 294 submittal must be received no later than the due date for what would have been the next semi-annual report.

d. Reporting to NASA Headquarters (SF 295--Semi-annual)

The Contractor shall prepare and submit Standard Form 295 (Rev. 12-98), "Summary Subcontract Report" in accordance with the instructions on the back of the form and in accordance with NASA FAR Supplement clause 1852.219-75, "Small Business Subcontracting Reporting" of this contract.

The SF 295 must be submitted to "NASA, Office of Procurement, Code HS, Washington, D.C. 20546-0001" on an semi-annual basis no later than April 30 and October 30 each year for the reporting periods ending March 31 and September 30, respectively.

e. Subcontractor Reporting

FAR clause 52.219-9 and NASA FAR Supplement clause 1852.219-75 require that the Contractor ensure that SF 294 and SF 295 reports are submitted by those subcontractors that have been required to adopt a Subcontracting Plan under the terms of the clause. These subcontractor reports must be submitted as required by paragraphs (c)and (d) above. The reports may be submitted though the Contractor or submitted directly. Regardless, the Contractor is responsible for ensuring proper and timely submittal of the required reports.

(End of clause)

H.4 SMALL DISADVANTAGED BUSINESS PARTICIPATION--CONTRACT TARGETS (GSFC 52.219-91) (AUG 2001)

(a) This clause does not apply to, and should not be completed by, Small Disadvantaged Business (SDB) offerors unless the SDB offeror has waived the price adjustment evaluation adjustment [see para (c.) of FAR clause 52.219-23].

(b) FAR 19.1202-4(a) requires that SDB subcontracting targets be incorporated in the contract. Targets for this contract are as follows:

*NAICS Industry Subsectors	Dollar Target	Percent of Contract Value
	N/A	
	Total	

*North American Industry Classification System (NAICS) Industry Subsectors as determined by the Department of Commerce

(c.) FAR 19.1202-4(b) requires that SDB concerns that are specifically identified by the offeror be listed in the contract when the extent of the identification of such subcontractors was part of the SDB

evaluation subfactor. SDB concerns (subcontractors) specifically identified by the offeror are as follows:

Name of Concern(s)

The contractor shall notify the Contracting Officer of any substitutions of firms that are not SDB concerns.

(d) If the prime offeror is an SDB that has waived the price evaluation adjustment, the target for the work it intends to perform as a prime contractor is as follows:

Dollars Percent of Contract Value

(End of clause)

H.5 EXPORT LICENSES (1852.225-70) (FEB 2000)

(a) The Contractor shall comply with all U.S. export control laws and regulations, including the International Traffic in Arms Regulations (ITAR), 22 CFR Parts 120 through 130, and the Export Administration Regulations (EAR), 15 CFR Parts 730 through 799, in the performance of this contract. In the absence of available license exemptions/exceptions, the Contractor shall be responsible for obtaining the appropriate licenses or other approvals, if required, for exports of hardware, technical data, and software, or for the provision of technical assistance.

(b) The Contractor shall be responsible for obtaining export licenses, if required, before utilizing foreign persons in the performance of this contract, including instances where the work is to be performed on-site at any Government installation, where the foreign person will have access to export-controlled technical data or software.

(c) The Contractor shall be responsible for all regulatory record keeping requirements associated with the use of licenses and license exemptions/exceptions.

(d) The Contractor shall be responsible for ensuring that the provisions of this clause apply to its subcontractors.

(End of clause)

H.6 LIMITATION OF FUNDS (FIXED-PRICE CONTRACT) (1852.232-77) (MAR 1989)

(a) Of the total price of the total price of the basic effort, the sum of $2,399,312 is presently available for payment and allotted to this contract. It is anticipated that from time to time additional

funds will be allocated to the contract in accordance with the following schedule, until the total price of said item is allotted:

SCHEDULE FOR ALLOTMENT OF FUNDS

Date Amounts

UPON AVAILABILITY OF FUNDS

(b) The Contractor agrees to perform or have performed work on the items specified in paragraph (a) above up to the point at which, if this contract is terminated pursuant to the Termination for Convenience of the Government clause of this contract, the total amount payable by the Government (including amounts payable for subcontracts and settlement costs) pursuant to paragraphs (f) and (g) if that clause would, in the exercise of reasonable judgment by the Contractor, approximate the total amount at the time allotted to the contract. The Contractor is not obligated to continue performance of the work beyond that point. The Government is not obligated in any event to pay or reimburse the Contractor more than the amount from time to time allotted to the contract, anything to the contrary in the Termination for Convenience of the Government clause notwithstanding.

(c) (1) It is contemplated that funds presently allotted to this contract will cover the work to be performed until March 1, 2007.

(2) If funds allotted are considered by the Contractor to be inadequate to cover the work to be performed until that date, or an agreed date substituted for it, the Contractor shall notify the Contracting Officer in writing when within the next 60 days the work will reach a point at which, if the contract is terminated pursuant to the Termination for Convenience of the Government clause of this contract, the total amount payable by the Government (including amounts payable for subcontracts and settlement costs) pursuant to paragraphs (f) and (g) of that clause will approximate 75 percent of the total amount then allotted to the contract.

(3) (i) The notice shall state the estimated date when the point referred to in subparagraph (2) above will be reached and the estimated amount of additional funds required to continue performance to the date specified in subparagraph (1) above, or an agreed date substituted for it.

(ii) The Contractor shall, 60 days in advance of the date specified in subparagraph (1) above, or an agreed date substituted for it, advise the Contracting Officer in writing as to the estimated amount of additional funds required for the timely performance of the contract for a further period as may be specified in the contract or otherwise agreed to by the parties.

(4) If, after the notification referred to in subdivision (3)(ii) above, additional funds are not allotted by the date specified in subparagraph (1) above, or an agreed date substituted for it, the Contracting Officer shall, upon the Contractor's written request, terminate this contract on that date or on the date set forth in the request, whichever is later, pursuant to the Termination for Convenience of the Government clause.

(d) When additional funds are allotted from time to time for continued performance of the work under this contract, the parties shall agree on the applicable period of contract performance to be covered by these funds. The provisions of paragraphs (b) and (c) above shall apply to these additional allotted funds and substituted date pertaining to them, and the contract shall be modified accordingly.

(e) If, solely by reason of the Government's failure to allot additional funds in amounts sufficient for the timely performance of this contract, the Contractor incurs additional costs or is delayed in the performance of the work under this contract, and if additional funds are allotted, an equitable adjustment shall be made in the price or prices (including appropriate target, billing, and ceiling prices where applicable) of the items to be delivered, or in the time of delivery or both.

(f) The Government may at any time before termination, and, with the consent of the Contractor, after notice of termination, allot additional funds for this contract.

(g) The provisions of this clause with respect to termination shall in no way be deemed to limit the rights of the Government under the Default clause of this contract. The provisions of this Limitation of Funds clause are limited to the work on and allotment of funds for the items set forth in paragraph (a) above. This clause shall become inoperative upon the allotment of funds for the total price of said work except for rights and obligations then existing under this clause.

(h) Nothing in this clause shall affect the right of the Government to terminate this contract pursuant to the Termination for Convenience of the Government clause of this contract.

(End of clause)

H.7 SAFETY AND HEALTH--ADDITIONAL REQUIREMENTS (GSFC 52.223-91) (OCT 2002)

(a) Other safety and health requirements. In addition to compliance with all Federal, state, and local laws as required by paragraph (b) of NFS clause 18-52.223-70, the Contractor shall comply with the following: None.

(b) Reporting. The immediate notification and prompt reporting required by paragraph (d) of NFS clause 1852.223-70 shall be to the to the Goddard Space Flight Center Safety and Environmental Branch, Code 205.2, Tel 301-286-2281 and to the Contracting Officer. This should be a verbal notification and confirmed by FAX or E-Mail. This notification is also required for any unsafe or environmentally hazardous condition associated with Government-owned property that is provided or made available for the performance of the contract.

(End of clause)

SECTION I OF NNG06ED46C
CONTRACT CLAUSES

I.1 CLAUSES INCORPORATED BY REFERENCE (52.252-2) (FEB 1998)

This contract incorporates one or more clauses by reference, with the same force and effect as if they were given in full text. Upon request, the Contracting Officer will make their full text available. Also, the full text of a clause may be accessed electronically at this/these address(es):

Federal Acquisition Regulation (FAR) clauses:

http://www.arnet.gov/far/

NASA FAR Supplement (NFS) clauses:

http://www.hq.nasa.gov/office/procurement/regs/nfstoc.htm

A. FAR CLAUSES INCORPORATED BY REFERENCE

(52.202-1)	DEFINITIONS (JULY 2004)
(52.203-3)	GRATUITIES (APR 1984)
(52.203-5)	COVENANT AGAINST CONTINGENT FEES (APR 1984)
(52.203-6)	RESTRICTIONS ON SUBCONTRACTOR SALES TO THE GOVERNMENT (JUL 1995)
(52.203-7)	ANTI-KICKBACK PROCEDURES (JUL 1995)
(52.203-8)	CANCELLATION, RESCISSION, AND RECOVERY OF FUNDS FOR ILLEGAL OR IMPROPER ACTIVITY (JAN 1997)
(52.203-10)	PRICE OR FEE ADJUSTMENT FOR ILLEGAL OR IMPROPER ACTIVITY (JAN 1997)
(52.203-12)	LIMITATION ON PAYMENTS TO INFLUENCE CERTAIN FEDERAL TRANSACTIONS (JUNE 2003)
(52.204-4)	PRINTED OR COPIED DOUBLE-SIDED ON RECYCLED PAPER (AUG 2000)
(52.204-7)	CENTRAL CONTRACTOR REGISTRATION (OCT 2003)
(52.209-6)	PROTECTING THE GOVERNMENT'S INTEREST WHEN SUBCONTRACTING WITH CONTRACTORS DEBARRED, SUSPENDED, OR PROPOSED FOR DEBARMENT (JAN 2005)
(52.211-5)	MATERIAL REQUIREMENTS (AUG 2000)
(52.215-2)	AUDIT AND RECORDS--NEGOTIATION (JUNE 1999)
(52.215-8)	ORDER OF PRECEDENCE--UNIFORM CONTRACT FORMAT (OCT 1997)
(52.215-11)	PRICE REDUCTION FOR DEFECTIVE COST OR PRICING DATA--MODIFICATION (OCT 1997)
(52.215-13)	SUBCONTRACTOR COST OR PRICING DATA--MODIFICATIONS (OCT 1997)
(52.215-14)	INTEGRITY OF UNIT PRICES (OCT 1997)

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CONTRACT CLAUSES

(52.219-4)	NOTICE OF PRICE EVALUATION ADJUSTMENT FOR HUBZone SMALL BUSINESS CONCERNS (JUL 2005){offeror elects to waive the evaluation preference [ ]}
(52.219-8)	UTILIZATION OF SMALL BUSINESS CONCERNS (MAY 2004)
(52.219-9)	SMALL BUSINESS SUBCONTRACTING PLAN (JAN 2002)
(52.219-16)	LIQUIDATED DAMAGES--SUBCONTRACTING PLAN (JAN 1999)
(52.219-23)	NOTICE OF PRICE EVALUATION ADJUSTMENT FOR SMALL DISADVANTAGED BUSINESS CONCERNS (JUL 2005)[the factor in para (b)is 10 percent} {offeror elects to waive adjustment [ ]}
52.219-25)	SMALL DISADVANTAGED BUSINESS PARTICIPATION PROGRAM--DISADVANTAGED STATUS AND REPORTING (OCT 1999)
(52.222-1)	NOTICE TO THE GOVERNMENT OF LABOR DISPUTES (FEB 1997)
(52.222-19)	CHILD LABOR--COOPERATION WITH AUTHORITIES AND REMEDIES (JUNE 2004)
(52.222-20)	WALSH-HEALEY PUBLIC CONTRACTS ACT (DEC 1996)
(52.222-21)	PROHIBITION OF SEGREGATED FACILITIES (FEB 1999)
(52.222-26)	EQUAL OPPORTUNITY (APR 2002)
(52.222-35)	EQUAL OPPORTUNITY FOR SPECIAL DISABLED VETERANS, VETERANS OF THE VIETNAM ERA, AND OTHER ELIGIBLE VETERANS (DEC 2001)
(52.222-36)	AFFIRMATIVE ACTION FOR WORKERS WITH DISABILITIES (AUG 1998)
(52.222-37)	EMPLOYMENT REPORTS ON SPECIAL DISABLED VETERANS, VETERANS OF THE VIETNAM ERA, AND OTHER ELIGIBLE VETERANS (DEC 2001)
(52.223-6)	DRUG FREE WORK PLACE (MAY 2001)
(52.223-14)	TOXIC CHEMICAL RELEASE REPORTING (AUG 2003)
(52.225-1)	BUY AMERICAN ACT--SUPPLIES (JUNE 2003)
(52.225-13)	RESTRICTIONS ON CERTAIN FOREIGN PURCHASES (MAR 2005)
(52.227-1)	AUTHORIZATION AND CONSENT (JUL 1995)
(52.227-2)	NOTICE AND ASSISTANCE REGARDING PATENT AND COPY-RIGHT INFRINGEMENT (AUG 1996)
(52.227-11)	PATENT RIGHTS--RETENTION BY CONTRACTOR (SHORT FORM) (JUN 1997) as modified by NASA FAR Supplement 1852.227-11
(52.227-14)	RIGHTS IN DATA-GENERAL (JUN 1987) as modified by NASA FAR Supplement 1852.227-14
(52.227-16)	ADDITIONAL DATA REQUIREMENTS (JUN 1987)
(52.229-3)	FEDERAL, STATE, AND LOCAL TAXES (APR 2003)
(52.230-2)	COST ACCOUNTING STANDARDS (APR 1998)
(52.230-6)	ADMINISTRATION OF COST ACCOUNTING STANDARDS (APR 2005)
(52.232-1)	PAYMENTS (APR 1984)
(52.232-8)	DISCOUNTS FOR PROMPT PAYMENT (FEB 2002)
(52.232-9)	LIMITATION ON WITHHOLDING OF PAYMENTS (APR 1984)
(52.232-11)	EXTRAS (APR 1984)
(52.232-17)	INTEREST (JUN 1996)
(52.232-18)	AVAILIBILITY OF FUNDS (APR 1984)

(52.232-23)	ASSIGNMENT OF CLAIMS (JAN 1986)
(52.232-25)	PROMPT PAYMENT (OCT 2003)
(52.232-34)	PAYMENT BY ELECTRONIC FUNDS TRANSFER--OTHER THAN CENTRAL CONTRACTOR REGISTRATION (MAY 1999)[para (b)(1) fill-in (hereafter: "designated office"--Cost and Commercial Accounts Department, Code 155, NASA/Goddard Space Flight Center, Greenbelt, MD 20771, FAX 301-286-1748, no later than concurrent with the first request for payment.]
(52.233-1)	DISPUTES (JULY 2002)--ALTERNATE I (DEC 1991)
(52.233-3)	PROTEST AFTER AWARD (AUG 1996)
(52.233-4)	APPLICABLE LAW FOR BREACH OF CONTRACT CLAIM (OCT 2004)
(52.242-13)	BANKRUPTCY (JUL 1995)
(52.243-1)	CHANGES--FIXED PRICE (AUG 1987)
(52.243-6)	CHANGE ORDER ACCOUNTING (APR 1984)
(52.244-2)	SUBCONTRACTS (MAR 2005)--ALTERNATE I (AUG 1998) {paragraph (e) is "Professional and consultant costs as defined at FAR 31.205-33" and paragraph (k) is "None"}
(52.244-5)	COMPETITION IN SUBCONTRACTING (DEC 1996)
(52.245-2)	GOVERNMENT PROPERTY (FIXED PRICE CONTRACTS) (MAY 2004)
(52.246-24)	LIMITATION OF LIABILITY--HIGH VALUE ITEMS (FEB 1997)
(52.247-67)	SUBMISSION OF COMMERCIAL TRANSPORTATION BILLS TO THE GENERAL SERVICES ADMINISTRATION FOR AUDIT (JUN 1997)
(52.248-1)	VALUE ENGINEERING (FEB 2000)
(52.249-2)	TERMINATION FOR CONVENIENCE OF THE GOVERNMENT (FIXED PRICE) (MAY 2004)
(52.249-8)	DEFAULT (FIXED PRICE SUPPLY AND SERVICE) (APR 1984)
(52.253-1)	COMPUTER GENERATED FORMS (JAN 1991)

B. NASA FAR SUPPLEMENT-CLAUSES INCORPORATED BY REFERENCE

(1852.215-84)	OMBUDSMAN (OCT 2003) The installation Ombudsman is Dorothy C. Perkins, Goddard Space Flight Center, Mailstop 100, Greenbelt, MD 20771, Business Phone: 301 286-5066, Fax 301 286-1714, E-mail address: Dorothy.C.Perkins@nasa.gov
(1852.219-76)	NASA 8 PERCENT GOAL (JUL 1997)
(1852.243-71)	SHARED SAVINGS (MAR 1997)
(1852.245-73)	FINANCIAL REPORTING OF NASA PROPERTY IN THE CUSTODY OF CONTRACTORS (OCT 2003)

(End of By Reference Section)

I.2 NOTIFICATION OF EMPLOYEE RIGHTS CONCERNING PAYMENT OF UNION DUES OR FEES (DEC 2004) (52.222-39)

(a) *Definition.* As used in this clause-"United States" means the 50 States, the District of Columbia, Puerto Rico, the Northern Mariana Islands, American Samoa, Guam, the U.S. Virgin Islands, and Wake Island.

(b) Except as provided in paragraph (e) of this clause, during the term of this contract, the Contractor shall post a notice, in the form of a poster, informing employees of their rights concerning union membership and payment of union dues and fees, in conspicuous places in and about all its plants and offices, including all places where notices to employees are customarily posted. The notice shall include the following information (except that the information pertaining to National Labor Relations Board shall not be included in notices posted in the plants or offices of carriers subject to the Railway Labor Act, as amended (45 U.S.C. 151-188)).

Notice to Employees

Under Federal law, employees cannot be required to join a union or maintain membership in a union in order to retain their jobs. Under certain conditions, the law permits a union and an employer to enter into a union-security agreement requiring employees to pay uniform periodic dues and initiation fees. However, employees who are not union members can object to the use of their payments for certain purposes and can only be required to pay their share of union costs relating to collective bargaining, contract administration, and grievance adjustment.

If you do not want to pay that portion of dues or fees used to support activities not related to collective bargaining, contract administration, or grievance adjustment, you are entitled to an appropriate reduction in your payment. If you believe that you have been required to pay dues or fees used in part to support activities not related to collective bargaining, contract administration, or grievance adjustment, you may be entitled to a refund and to an appropriate reduction in future payments.

For further information concerning your rights, you may wish to contact the National Labor Relations Board (NLRB) either at one of its Regional offices or at the following address or toll free number:

National Labor Relations Board
Division of Information
1099 14th Street, N.W.
Washington, D.C. 20570
1-866-667-6572
1-866-316-6572 (TTY)

To locate the nearest NLRB office, see NLRB's website at *http://www.nlrb.gov.*

(c) The Contractor shall comply with all provisions of Executive Order 13201 of February 17, 2001, and related implementing regulations at 29 CFR part 470, and orders of the Secretary of Labor.

(d) In the event that the Contractor does not comply with any of the requirements set forth in paragraphs (b), (c), or (g), the Secretary may direct that this contract be cancelled, terminated, or suspended in whole or in part, and declare the Contractor ineligible for further Government contracts in accordance with procedures at 29 CFR part 470, Subpart B-Compliance Evaluations, Complaint Investigations and

Enforcement Procedures. Such other sanctions or remedies may be imposed as are provided by 29 CFR part 470, which implements Executive Order 13201, or as are otherwise provided by law.

(e) The requirement to post the employee notice in paragraph (b) does not apply to-
(1) Contractors and subcontractors that employ fewer than 15 persons;
(2) Contractor establishments or construction work sites where no union has been formally recognized by the Contractor or certified as the exclusive bargaining representative of the Contractor's employees;
(3) Contractor establishments or construction work sites located in a jurisdiction named in the definition of the United States in which the law of that jurisdiction forbids enforcement of union-security agreements;
(4) Contractor facilities where upon the written request of the Contractor, the Department of Labor Deputy Assistant Secretary for Labor-Management Programs has waived the posting requirements with respect to any of the Contractor's facilities if the Deputy Assistant Secretary finds that the Contractor has demonstrated that-
(i) The facility is in all respects separate and distinct from activities of the Contractor related to the performance of a contract; and
(ii) Such a waiver will not interfere with or impede the effectuation of the Executive order; or
(5) Work outside the United States that does not involve the recruitment or employment of workers within the United States.

(f) The Department of Labor publishes the official employee notice in two variations; one for contractors covered by the Railway Labor Act and a second for all other contractors. The Contractor shall-
(1) Obtain the required employee notice poster from the Division of Interpretations and Standards, Office of Labor-Management Standards, U.S. Department of Labor, 200 Constitution Avenue, NW, Room N-5605, Washington, DC 20210, or from any field office of the Department's Office of Labor-Management Standards or Office of Federal Contract Compliance Programs;
(2) Download a copy of the poster from the Office of Labor-Management Standards website at *http://www.olms.dol.gov*; or
(3) Reproduce and use exact duplicate copies of the Department of Labor's official poster.

(g) The Contractor shall include the substance of this clause in every subcontract or purchase order that exceeds the simplified acquisition threshold, entered into in connection with this contract, unless exempted by the Department of Labor Deputy Assistant Secretary for Labor-Management Programs on account of special circumstances in the national interest under authority of 29 CFR 470.3(c). For indefinite quantity subcontracts, the Contractor shall include the substance of this clause if the value of orders in any calendar year of the subcontract is expected to exceed the simplified acquisition threshold. Pursuant to 29 CFR part 470, Subpart B-Compliance Evaluations, Complaint Investigations and Enforcement Procedures, the Secretary of Labor may direct the Contractor to take such action in the enforcement of these regulations, including the imposition of sanctions for noncompliance with respect to any such subcontract or purchase order. If the Contractor becomes involved in litigation with a subcontractor or vendor, or is threatened with such involvement, as a result of such direction, the Contractor may request the United States, through the Secretary of Labor, to enter into such litigation to protect the interests of the United States.

(End of clause)

I.3 NOTIFICATION OF CHANGES (52.243-7) (APR 1984)

(a) Definitions. "Contracting Officer," as used in this clause, does not include any representative of the Contracting Officer. "Specifically authorized representative (SAR)," as used in this clause, means any person the Contracting Officer has so designated by written notice (a copy of which shall be provided to the Contractor) which shall refer to this subparagraph and shall be issued to the designated representative before the SAR exercises such authority.

(b) Notice. The primary purpose of this clause is to obtain prompt reporting of Government conduct that the Contractor considers to constitute a change to this contract. Except for changes identified as such in writing and signed by the Contracting Officer, the Contractor shall notify the Administrative Contracting Officer in writing promptly, within 30 calendar days from the date that the Contractor identifies any Government conduct (including actions, inactions, and written or oral communications) that the Contractor regards as a change to the contract terms and conditions. On the basis of the most accurate information available to the Contractor, the notice shall state--

(1) The date, nature, and circumstances of the conduct regarded as a change;

(2) The name, function, and activity of each Government individual and Contractor official or employee involved in or knowledgeable about such conduct;

(3) The identification of any documents and the substance of any oral communication involved in such conduct;

(4) In the instance of alleged acceleration of scheduled performance or delivery, the basis upon which it arose;

(5) The particular elements of contract performance for which the Contractor may seek an equitable adjustment under this clause, including--

(i) What contract line items have been or may be affected by the alleged change,

(ii) What labor or materials or both have been or may be added, deleted, or wasted by the alleged change;

(iii) To the extent practicable, what delay and disruption in the manner and sequence of performance and effect on continued performance have been or may be caused by the alleged change;

(iv) What adjustments to contract price, delivery schedule, and other provisions affected by the alleged change are estimated; and

(6) The Contractor's estimate of the time by which the Government must respond to the Contractor's notice to minimize cost, delay or disruption of performance.

(c) Continued performance. Following submission of the notice required by (b) above, the Contractor shall diligently continue performance of this contract to the maximum extent possible in accordance with its terms and conditions as construed by the Contractor, unless the notice reports a direction of the Contracting Officer or a communication from a SAR of the Contracting Officer, in either of which events the Contractor shall continue performance; provided, however, that if the Contractor regards the direction or communication as a change as described in (b) above, notice shall be given in the manner provided. All directions, communications, interpretations, orders and similar actions of the SAR shall be reduced to writing promptly and copies furnished to the Contractor and to the Contracting Officer. The Contracting Officer shall promptly countermand any action which exceeds the authority of the SAR.

(d) Government response. The Contracting Officer shall promptly, within 30 calendar days after receipt of notice, respond to the notice in writing. In responding, the Contracting Officer shall either--

(1) Confirm that the conduct of which the Contractor gave notice constitutes a change and when necessary direct the mode of further performance;

(2) Countermand any communication regarded as a change;

(3) Deny that the conduct of which the Contractor gave notice constitutes a change and when necessary direct the mode of further performance; or

(4) In the event the Contractor's notice information is inadequate to make a decision under (1), (2), or (3) above, advise the Contractor what additional information is required, and establish the date by which it should be furnished and the date thereafter by which the Government will respond.

(e) Equitable adjustments. (1) If the Contracting Officer confirms that Government conduct effected a change as alleged by the Contractor, and the conduct causes an increase or decrease in the Contractor's cost of, or the time required for, performance of any part of the work under this contract, whether changed or not changed by such conduct, an equitable adjustment shall be made--

(i) In the contract price or delivery schedule or both; and

(ii) In such other provisions of the contract as may be affected.

(2) The contract shall be modified in writing accordingly. In the case of drawings, designs or specifications which are defective and for which the Government is responsible, the equitable adjustment shall include the cost and time extension for delay reasonably incurred by the Contractor in attempting to comply with the defective drawings, designs or specifications before the Contractor identified, or reasonably should have identified, such defect. When the cost of property made obsolete or excess as a result of a change confirmed by the Contracting Officer under this clause is included in the equitable adjustment, the Contracting Officer shall have the right to prescribe the manner of

disposition of the property. The equitable adjustment shall not include increased costs or time extensions for delay resulting from the Contractor's failure to provide notice or to continue performance as provided, respectively, in (b) and (c) above.

NOTE: The phrases "contract price" and "cost" wherever they appear in the clause, may be appropriately modified to apply to cost-reimbursement or incentive contracts, or to combinations thereof.

(End of clause)

I.4 SUBCONTRACTS FOR COMMERCIAL ITEMS (52.244-6) (DEC 2004)

(a) Definitions. As used in this clause--
"Commercial item," has the meaning contained in Federal Acquisition Regulation 2.101, Definitions.
"Subcontract," includes a transfer of commercial items between divisions, subsidiaries, or affiliates of the Contractor or subcontractor at any tier.

(b) To the maximum extent practicable, the Contractor shall incorporate, and require its subcontractors at all tiers to incorporate, commercial items or nondevelopmental items as components of items to be supplied under this contract.

(c)(1) The following clauses shall be flowed down to subcontracts for commercial items:

(i) 52.219-8, Utilization of Small Business Concerns (MAY 2004) (15 U.S.C. 637(d)(2) and (3)), in all subcontracts that offer further subcontracting opportunities. If the subcontractor (except contracts to small business concerns) exceeds $500,000 ($1,000,000 for construction of any public facility), the subcontractor must include 52.219-8 in lower tier subcontracts that offer subcontracting opportunities.

(ii) 52.222-26, Equal Opportunity (APR 2002)(E.O. 11246).

(iii) 52.222-35, Equal Opportunity for Special Disabled Veterans, Veterans of the Vietnam Era, and Other Eligible Veterans (DEC 2001)(38 U.S.C. 4212(a)).

(iv) 52.222-36, Affirmative Action for Workers with Disabilities (JUN 1998)(29 U.S.C. 793).

(v) 52.222-39 Notification of Employee Rights Concerning Payment of Union Dues or Fees (DEC 2004) (E.O. 13201). (Flow down as required in accordance of paragraph (g) of FAR clause 52.222-39).

(vi) 52.247-64, Preference for Privately Owned U.S.-Flag Commercial Vessels (JUN 2000)(46 U.S.C. Appx 1241 and 10 U.S.C. 2631) (flow down required in accordance with paragraph (d) of FAR clause 52.247-64).

(2) While not required, the Contractor may flow down to subcontracts for commercial items a minimal number of additional clauses necessary to satisfy its contractual obligations.

(d) The Contractor shall include the terms of this clause, including this paragraph (d), in subcontracts awarded under this contract.

(End of clause)

I.5 USE OF RURAL AREA SMALL BUSINESSES (1852.219-74) (SEP 1990)

(a) Definitions.
"Rural area" means any county with a population of fewer than twenty thousand individuals.
"Small business concern," as used in this clause, means a concern, including its affiliates, that is independently owned and operated, not dominant in the field of operation in which it is bidding under this contract, and qualified as a small business under the criteria and size standards in 13 CFR 121.
(b) NASA prime and subcontractors are encouraged to use their best efforts to award subcontracts to small business concerns located in rural areas.
(c) Contractors acting in good faith may rely on written representations by their subcontractors regarding their status as small business concerns located in rural areas.
(d) The Contractor agrees to insert the provisions of this clause, including this paragraph (d), in all subcontracts hereunder that offer subcontracting possibilities.

(End of clause)

I.6 SMALL BUSINESS SUBCONTRACTING REPORTING (1852.219-75) (MAY 1999)

(a) The Contractor shall submit the Summary Subcontract Report (Standard Form (SF) 295) semiannually for the reporting periods specified in block 4 of the form. All other instructions for SF 295 remain in effect.
(b) The Contractor shall include this clause in all subcontracts that include the clause at FAR 52.219-9.

(End of clause)

I.7 CENTER FOR AEROSPACE INFORMATION (1852.235-70) (FEBRUARY 2003)

(a) The Contractor should register with and avail itself of the services provided by the NASA Center for AeroSpaceInformation (CASI) (http://www.sti.nasa.gov) for the conduct of research or research and development required under this contract. CASI provides a variety of services and products as a NASA repository and database of research information, which may enhance contract performance.
(b) Should the CASI information or service requested by the Contractor be unavailable or not in the exact form necessary by the Contractor, neither CASI nor NASA is obligated to search for or change the format of the information. A failure to furnish information shall not entitle the Contractor to an equitable adjustment under the terms and conditions of this contract.
(c) Information regarding CASI and the services available can be obtained at the Internet address contained in paragraph (a) of this clause or at the following address.
Center for AeroSpace Information (CASI)

7121 Standard Drive
Hanover, Maryland 21076-1320
Email: help@sti.nasa.gov
Phone: 301-621-0390 FAX: 301-621-0134

(End of clause)

SECTION J OF NNG06ED46C
LIST OF ATTACHMENTS

J.1 LIST OF ATTACHMENTS (GSFC 52.211-101) (OCT 1988)

The following attachments constitute part of this contract:

Attachment	Description	Date	No. of Pages
A	Statement of Work (SOW) (431-SOW-000303)	February 8, 2006	34
B	Performance Specification (431-SPEC-000121)	February 8, 2006	84
C	Deliverable Items List and Schedule (431-LIST-000304)	February 8, 2006	9
D	Small Business Subcontracting Plan	March 31, 2006	12
E	Safety and Health Plan	April 14, 2006	6

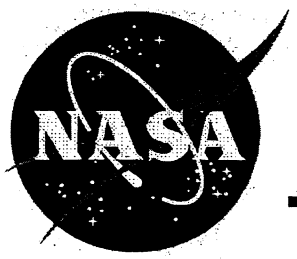
(End of clause)

431-SOW-000303
Revision -

Lunar Reconnaissance Orbiter Project

S-Band Telemetry, Tracking and Command Subsystem Statement of Work

February 8, 2006



Goddard Space Flight Center
Greenbelt, Maryland

National Aeronautics and Space Administration

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1.0 INTRODUCTION

1.1 GENERAL INFORMATION

The Lunar Reconnaissance Orbiter (LRO) mission objective is to conduct investigations that will be specifically targeted to prepare for and support future exploration of the Moon. This includes:

- Characterization of the lunar radiation environment, biological impacts, and potential mitigation.
- Key aspects of this objective include determining the global radiation environment, investigating the capabilities of potential shielding materials, and validating deep space radiation prototype hardware and software.
- Develop a high-resolution global, three-dimensional geodetic grid of the Moon and provide the topography necessary for selecting future landing sites.
- Assess in detail the resources and environments of the Moon's polar regions.
- High spatial resolution assessment of the Moon's surface addressing elemental composition, mineralogy, and regolith characteristics.
- The on-board S-Band transponder will be used to receive commands and transmit telemetry and tracking data to Earth-based ground stations.

This document defines the work to be performed for Contractor design, development, fabrication, and delivery of the S-Band Telemetry, Tracking and Command (TT&C) Subsystem for the LRO Mission.

1.2 GENERAL REQUIREMENTS

The Contractor shall provide the facilities, personnel, services, tools, equipment, and materials necessary to design, analyze, manufacture, inspect, test, and deliver:

- One (1) Protoflight S-Band Transponder
- One (1) Flight Unit S-Band Transponder
- Five (5) Flight Unit S-Band RF Diplexers
- Three (3) Flight Unit RF Transfer Switch
- Three (3) Flight Unit S-Band Directional Coupler
- Necessary cabling, connections, harness and other interconnects required to integrate these components into a Protoflight and a Flight S-Band TT&C Subsystem

The Contractor shall generate a matrix listing each section in this document reflecting either compliance or non-compliance. Areas of non-compliance need to be addressed by the Contractor showing how they plan to meet the requirement(s) or why it will remain non-compliant.

2.0 APPLICABLE AND REFERENCED DOCUMENTS

All applicable and reference documentation identified in this document shall apply in the situations where they are specifically referenced. In the event of a conflict between this document and the Lunar Reconnaissance Orbiter S-Band Telemetry, Tracking and Command Subsystem Performance Specification (431-SPEC-000121), this document shall take precedence.

2.1 APPLICABLE DOCUMENTS

431-LIST-000304	Lunar Reconnaissance Orbiter S-Band Telemetry, Tracking and Command Subsystem Deliverable Items List and Schedule
431-PLAN-000131	Spacecraft/Orbiter Performance Assurance Implementation Plan
431-PROC-000179	Lunar Reconnaissance Orbiter Project Configuration Management Procedure
431-PROC-000180	Reconnaissance Orbiter Data Management Procedure
431-RQMT-000174	Lunar Reconnaissance Orbiter Mission Assurance Requirements
431-SPEC-000121	Lunar Reconnaissance Orbiter S-Band Telemetry, Tracking and Command Performance Specification
GPR-8730.1	Calibration and Metrology GSFC Procedural Requirements

2.2 REFERENCED DOCUMENTS

431-HDBK-000093	LRO Component Mechanical Interface Control Drawing Guidelines Handbook
541-PG-8072.1.2	GSFC Fastener Integrity Requirement Procedures and Guidelines
ANSI/ESD S20.20	Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)
ASTM E-595	Standard Test Method for Total Mass Loss and Collected Volatile, Condensable Materials for Outgassing
EEE-INST-002	Instructions for EEE Parts Selection, Screening, Qualification, and De-rating
GPR 7120.1	Program and Project Management Goddard Procedural Requirements
GSFC S312-P-003	Procurement Specification for Rigid Printed Boards for Space Applications and Other High Reliability Uses
GSFC-STD-7000	General Environmental Verification Specification (GEVS) for GSFC Flight Programs and Projects
IEST-STD-CC1246	Product Cleanliness Levels and Contamination Control Program
IPC-2221	Generic Standard on Printed Board Design
IPC-2222	Sectional Design Standard for Rigid Organic Printed Boards
IPC-2223	Sectional Design Standard for Flexible Printed Boards
IPC-6011	Generic Performance Specification for Printed Boards

IPC-6012	Qualification and Performance Specification for Rigid Printed Boards
IPC-6013	Qualification and Performance Specification for Flexible Printed Boards
IPC-A-600	Acceptability of Printed Boards
IPC-D-275	Design Standard for Rigid Printed Boards and Rigid Printed Board Assemblies
MIL-STD-889	Dissimilar Materials
MIL-STD-1629	Procedures for performing an FMEA
MSFC-STD-3029	Selection of Metallic Materials for Stress Corrosion Cracking Resistance
NASA-8739.2	Workmanship Standard for Surface Mount Technology
NASA-STD-8739.1	Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies
NASA-STD-8739.3	Soldered Electrical Connection
NASA-STD-8739.4	Crimping, Interconnecting Cables, Harnesses, and Wiring
NASA-STD-8739.5	Fiber Optic Terminations, Cable Assemblies, and Installation
NASA-STD-8739.7	Electrostatic Discharge Control (Excluding Electrically Initiated Explosive Devices)

3.0 MANAGEMENT, REPORTING, DOCUMENTATION AND REVIEWS

3.1 MANAGEMENT AND REPORTING

The Contractor shall designate a single individual who will be given full responsibility and authority to manage and administer all phases of the work specified by the contract, and ensure that all objectives are accomplished within schedule and cost constraints.

The Contractor shall designate and identify by name a single individual who shall serve as a point of contact with the Goddard Space Flight Center (GSFC) Contracting Officer Technical Representative (COTR) for all technical aspects of the LRO S-Band TT&C Subsystem.

The Contractor shall provide for managing all resources, controlling schedules, managing all engineering, manufacturing and procurement activities, configuration management (CM), quality assurance (QA), documentation control, and distribution.

The Contractor shall prepare and present to the National Aeronautics and Space Administration (NASA)/GSFC COTR monthly status via telecom and a written report. The report shall be a summary presentation of the period's progress, problem areas, and activities on-going and planned. The Contractor shall generate a list of significant milestones that will enable the NASA/GSFC COTR to ascertain program progress.

In addition, every week, on an agreed day by both the COTR and Contractor, the later shall provide an informal report through email on the current status of the TT&C Subsystem for that particular week. It should also comment on situations developed since the last report and developments planned for the following week. Additionally, it should also comment on potential problems the contractor might foresee that could affect the contract development, if any. An informal and short telephone call might follow to clarify questions and discuss issues.

3.2 DOCUMENTATION

The Contractor shall ensure the generation and delivery of all documentation as called for in the Contract.

In addition to that documentation specifically called for in the Contract, upon request by the NASA/GSFC COTR, the Contractor shall make available a copy of any document or data generated during this contract performance for review by the GSFC. This includes, but is not limited to, technical reports and memorandums, drawings, schematics, studies, analyses, parts and materials data, test data, alerts, etc.

3.3 REVIEWS AND MEETINGS

The following reviews shall be performed to fulfill the requirements as detailed within the Program and Project Goddard Procedural Requirements (GPR 7120.1)

3.3.1 Preliminary Design Review

The Contractor shall organize and present a Preliminary Design Review (PDR) to a GSFC Review Team at the Contractor's facility, unless otherwise agreed to by the Contractor and GSFC, on a date defined in the contract. The PDR shall demonstrate that the preliminary design

meets requirements for the system of interest with acceptable risk. The review shall show that the correct design option has been selected, interfaces identified, and verification methods have been satisfactorily described. An understanding of all interfaces, mechanical and thermal, and necessary interactions with the GSFC design team, as described in Sections 4.3 and 4.4, shall be demonstrated. The Review presentation package shall address all program management, design, analysis, manufacturing, test, and QA activities outlined in this document and the Lunar Reconnaissance Orbiter S-Band Telemetry, Tracking and Command Subsystem Performance Specification (431-SPEC-000121) in sufficient detail to meet the review requirements. This review shall cover programmatic, technical, test and verification, and QA topics. This review shall provide an opportunity to review drawings and all analyses before the expenditure of large scale resource, and shall establish the basis for proceeding with the detailed design.

The Contractor shall provide to GSFC a PDR Presentation Package and all other required deliverable data in accordance with the contract schedule. Refer to Section 4.2.3 and the contract schedule for the list of required deliverable data.

Review minutes shall be prepared and, as a minimum, shall include attendance, action items, action item accomplishment responsibility and agreements. All items shall be in sufficient detail to be self-explanatory. A Design Review Report shall be prepared following the review and, as a minimum, contain meeting notice, agenda, review meeting minutes described above and responses to all recommendations and action items.

3.3.2 Critical Design Review

The Contractor shall organize and present a Critical Design Review (CDR) to a GSFC Review Team at the Contractor's facility, unless otherwise agreed to by the Contractor and GSFC, on a date defined in the contract. The CDR shall demonstrate a final detailed design using completed drawings and analyses. The review shall demonstrate overall conformance of the requirements specified in the Lunar Reconnaissance Orbiter S-Band Telemetry, Tracking and Command Subsystem Performance Specification (431-SPEC-000121) and this document. Drawings and analyses should be released or ready for final review and approval. An implementation of all interfaces, mechanical and thermal, and necessary interactions with the GSFC design team, as described in Sections 4.3 and 4.4, shall be demonstrated. The review shall also include a manufacturing readiness, materials, quality control, and processes intended for production. This review shall cover programmatic, technical, test and verification, and QA topics. This review shall provide an opportunity to review drawings and all analyses before the start of Flight Unit fabrication.

The Contractor shall provide to GSFC a CDR Presentation Package and all other required deliverable data in accordance with the contract schedule. Refer to Section 4.2.4 and the contract schedule for the list of required deliverable data.

Review minutes shall be prepared and, as a minimum, shall include attendance, action items, action item accomplishment responsibility and agreements. All items shall be in sufficient detail to be self-explanatory. A Design Review Report shall be prepared following the review and, as a minimum, contain meeting notice, agenda, review meeting minutes described above and responses to all recommendations and action items.

3.3.3 Pre-Environmental Review

The Contractor shall organize and conduct a Pre-Environmental Review (PER) at the Contractor's facility, unless otherwise agreed to by the Contractor and GSFC, before the environment test program begins. This review shall demonstrate overall conformance of the requirements specified in the Lunar Reconnaissance Orbiter S-Band Telemetry, Tracking and Command Subsystem Performance Specification (431-SPEC-000121) and this document for this phase of the procurement. This review shall cover programmatic, technical, test and verification, and QA topics. This review shall also provide an opportunity to review test plans and procedures and all analyses required to approve the testing of the hardware.

3.3.4 Pre-Shipment Review

The Contractor shall hold a Pre-Shipment Review (PSR) at the Contractor's facility, unless otherwise agreed to by the Contractor and GSFC, at the completion of verification tests and prior to shipment of the hardware to GSFC. A PSR shall be held prior to the delivery of each hardware item. A Data Delivery Package (Section 4.2.5) shall be presented for review at each PSR.

3.3.5 Technical Interchange Meetings

The Contractor shall plan for informal, face-to-face Technical Interchange Meetings (TIM) to be held at the facilities selected by GSFC. These TIMs shall support review and coordination of technical issues including, but not limited to, parts, test plans, test procedures, software changes, design modifications, and design analyses. The TIM meeting notice shall be seven calendar days in advance of each meeting.

3.3.6 Notification to NASA/GSFC Contracting Officer and Contracting Officer Technical Representative

The Contractor shall notify the NASA/GSFC COTR at least ten calendar days in advance of all mandatory hardware inspections, test activities, and deliveries at either the Contractor's or a sub-Contractor's facility to allow timely participation by the NASA/GSFC QA parties.

4.0 ENGINEERING

4.1 GENERAL REQUIREMENTS

The Contractor shall perform analyses of the technical and environmental requirements specified in the Lunar Reconnaissance Orbiter S-Band Telemetry, Tracking and Command Subsystem Performance Specification (431-SPEC-000121) to ensure compliance of the hardware fabrication and to assemble the documentation necessary to ensure its usability by NASA/GSFC users.

4.2 ENGINEERING DOCUMENTATION

The system engineering analyses of the detailed design and subsequent fabrication and assembly, test, and inspection of the Transponder shall result, as a minimum, in the following technical documentation, as required in the Contract. Contractor format is suitable for this documentation.

4.2.1 Interface Control Document

The Contractor shall provide a document or documents that define, in detail, all performance, functional, and environmental specifications and all electrical, thermal, and mechanical interfaces described in Lunar Reconnaissance Orbiter Mechanical Interface Control Drawing Guidelines Handbook (431-HDBK-000093). Thermal interface information shall include thermal coatings on exterior surfaces and internal telemetry locations. Draft, preliminary and final reports shall be provided in accordance with the Lunar Reconnaissance Orbiter S-Band Telemetry, Tracking and Command Subsystem Deliverable Items List and Schedule (431-LIST-000304).

4.2.2 Drawing Package

The Contractor shall provide a drawing package that includes, but is not limited to:

ELECTRICAL: assembly and interface drawings (board level schematics available on request)

MECHANICAL: assembly and interface drawings

SOFTWARE: flowcharts, control logic, architecture, and structure of embedded software

Preliminary and final reports shall be provided in accordance with the Lunar Reconnaissance Orbiter S-Band Telemetry, Tracking and Command Subsystem Deliverable Items List and Schedule (431-LIST-000304).

4.2.3 Preliminary Design Review Presentation Package

The Contractor shall provide a PDR Presentation Package prior to the PDR, as described in Section 3.3.1, per the contract schedule. The Review presentation package shall address all program management, design, analysis, manufacturing, test, and QA activities outlined in this SOW and the Lunar Reconnaissance Orbiter S-Band Telemetry, Tracking and Command Subsystem Performance Specification (431-SPEC-000121) in sufficient detail to meet the review requirements. At a minimum, the design package should cover the following areas:

- Program Management
- Preliminary design for the EU
- Functional/Performance Requirements compliance
- Mounting interface approach
- Physical Characteristics compliance
- Electrical Characteristics compliance
- Life Requirements compliance
- Environmental Requirements compliance
- Thermal design and analysis results, including GSFC interface
- Mechanical/Structural design and analyses results, including GSFC interface
- Quality Assurance
- Verification test plan (including performance test description)
- Coupon program plan
- Non-destructive examination and defect acceptance criteria for workmanship
- Radiation hardness assessment (if applicable)
- Manufacturing flow with inspection points
- Facilities
- Materials and Processes
- Contamination Control
- Flight Heritage
- Verification Matrix
- Handling Guidelines

4.2.4 Critical Design Review Presentation Package

The Contractor shall provide a CDR Presentation Package prior to the CDR, as described in Section 3.3.2, per the contract schedule. The Review presentation package shall address all program management, design, analysis, manufacturing, test, and QA activities outlined in this document and the Lunar Reconnaissance Orbiter Project S-Band Telemetry, Tracking and Command Subsystem Performance Specification (431-SPEC-000121) in sufficient detail to meet the review requirements. At a minimum, the design package should cover the following areas:

- Program Management
- Final detailed design for the Engineering and Flight Units
- Functional/Performance Requirements, demonstration of specification compliance
- Mounting interface implementation
- Physical Characteristics compliance
- Electrical Characteristics compliance
- Life Requirements compliance

- Environmental Requirements compliance
- Updates to any analyses presented at PDR
- Quality Assurance
- Verification test plan (including Performance Test Description)
- Coupon program plan and status
- Radiation hardness assessment (if applicable)
- Manufacturing flow with inspection points
- Facilities
- Materials and Processes
- Contamination Control
- Flight Heritage
- Verification Matrix
- Handling Guidelines

4.2.5 Data Delivery Package

The Data Delivery Package shall be made available for review during mandatory inspections and PSRs for each of the different hardware deliverables. This package shall also be delivered with each end item with the level of detail required of that item. The package should be comprised of, but not limited to, the following data:

All Items:

- As-Built vs. As-Designed Parts List, (includes serialization/revisions)
- Final Drawing Package (including rework instructions, if any)
- Critical Parameters Trend Data,
- Problem/anomaly reporting (complete copies of report)
- Deviations/Waivers/open items/nonconformances and their dispositions,
- Class I Material Review Board (MRB) complete copies of reports
- List of Materials and Processes used,
- Log of total operating time,
- List and status of all identified Life-Limited Items,
- Verification matrix, test data and reports,
- Flight connector mate/demate log (Flight Unit only)
- Photograph Documentation (Pre-Closure and Closed)
- Certificate of Conformance
- Performance Analysis Report
- Thermal Analysis Report
- List of Open Items with proposed closure dates

4.2.6 Verification Test Plan

A Verification Test Plan shall be generated by the contractor to perform verification tests identified in the Lunar Reconnaissance Orbiter Project S-Band Telemetry, Tracking and Command Subsystem Performance Specification (431-SPEC-000121) document. Verification tests must demonstrate acceptable performance over the specified range of performance requirements, measure performance parameters and reveal inadequacies in manufacturing and assembly such as workmanship or material problems.

The plan should state the purpose of each test, state acceptance criteria, describe in detail the test method and instrumentation, and give the sequence of the tests. The plan should include a test matrix summarizing all tests that will be performed on the Transponder.

This plan shall be a contractor controlled document and shall indicate all changes made after the initial approval by the GSFC. After verification test plan approval, no changes shall be made without written NASA/GSFC COTR approval. Preliminary and final reports shall be provided in accordance with the Lunar Reconnaissance Orbiter S-Band Telemetry, Tracking and Command Subsystem Deliverable Items List and Schedule (431-LIST-000304).

4.2.7 Verification Test Procedures

The Contractor shall generate Verification Test Procedures. The verification procedures shall be step-by-step instructions for performing tests outlined by the Verification Test Plan. The procedures should define the environmental conditions for the tests, required equipment and facilities, test constraints, use of diagnostic or performance test software, operating conditions, tolerance on all input stimuli, data to be recorded and pass/fail limits. Test procedures shall also include Safe-to-Mate procedures to verify that ground support equipment (GSE) can safely be mated to interfaces and that interfaces are safe to accept mating with the GSE.

Verification test procedures shall be contractor controlled documents and shall indicate all changes made after the initial release for review to the NASA/GSFC COTR. Any additional changes shall be provided to the NASA/GSFC COTR for review.

4.3 THERMAL ANALYSIS

The vendor thermal analysis shall show that the device and/or the electronic part junction temperatures are within the Electrical, Electronic, and Electromechanical (EEE) parts de-rating guidelines for operation in a vacuum environment. Analysis shall prove that component will be within junction derating temperatures when spacecraft thermal interface is at maximum qualification temperature and when component is operating at maximum power dissipation. By analysis or by similarity to other flight qualified parts, vendor shall also prove that start up at minimum survival temperature is not an issue. Thermal model and thermal model documentation as described below shall be provided with each Thermal Analysis Report. All analysis results shall be summarized in a Contractor-format for the Thermal Analyses Report, to be provided for review as per the contract schedule. LRO Thermal requires an analysis report at PDR, CDR, and at PSR.

4.3.1 Thermal Model

The Contractor shall provide a reduced thermal model with approximately 10 nodes (i.e., six nodes for exterior packaging box, four for interior components of interest). If 10 nodes are insufficient to capture appropriate internal to external resistances, then under agreement with LRO thermal systems lead, slightly larger models will be considered. The reduced thermal model shall also contain node(s) that approximately represents each internal telemetry point.

The thermal model will include an adequate level of detail to predict, under worst case hot, cold, and safe-hold conditions, all critical temperatures, including those that drive operational and survival temperature limits and heater power. Worst-case conditions will include a rational combination of the effects of design tolerances, fabrication uncertainties, material differences, and degradation due to aging. Models should use conservative property values for conduction, emission, and multi-layer insulation (MLI) effective emittance, and consider contact resistance.

4.3.2 Thermal Model Documentation

Model documentation shall identify the nodalization, the thermal couplings and masses such that the GSFC can recreate the model in the System Improved Numerical Differencing Analyzer (SINDA) thermal analyzer. It is preferable, however, that the vendor delivers the reduced model in SINDA format if convenient.

Thermal model documentation shall include, but not necessarily be limited to, the following information:

a. Graphical figures showing node locations and coordinate system
b. Graphical and/or table showing surface coatings matched to node numbers
c. Tables providing the following information

- Nodal thermal capacitance
- Linear node-to-node conductors
- Fixed radiation node-to-node conductors (if any).
- Array data (e.g., temperature dependent properties, time varying power arrays, etc.)
- Listing of nodes where operational and survival heater power is to be applied, associated nodes used for heater control, maximum heater power, heater ON/OFF set points, type of heater (bang-bang or proportional), and mission mode power profiles.
- Detailed description of any special logic/algorithms utilized (e.g., heater control logic, Variable Conductance Heat Pipe [VCHP] logic, Capillary Pumped Loop [CPL]/Looped Heat Pipe [LHP] logic, etc.). No proprietary code will be allowed.
- Detailed description of logic and use for any user provided subroutines
- Listing of component power dissipations and the nodes they are applied to
- Listing of materials used along with their applicable thermo-optical and material properties
- Listing correlating thermal model node(s) to each reference location where a monitored temperature sensor is placed

d. Listing of temperature limits assigned to monitored temperature sensor(s). The appropriate node number(s) in the thermal model will be identified. The following two types of temperature limits will be provided.

- Flight Operational limits
- Qualification limits

4.3.3 Thermal Testing

All components must be thermally cycled in a thermal vacuum chamber rather than in an air filled chamber. All components shall be flight like blanketed and cycled eight times with the thermal interface held at the qualification temperatures listed above at the thermal interface. Durations shall be four hours. If the component is sensitive to orbit transience, component performance shall be monitored during hot to cold transitions at a rate that a flight like orbit average case might experience.

Cold Start Requirement

All components shall demonstrate cold start from minimum survival temperature during thermal vacuum testing.

Survival Range Test

All components shall be exposed to hot and cold survival limits at the spacecraft interface during thermal vacuum testing.

4.4 STRUCTURAL ANALYSIS

A structural analysis shall be performed on the Flight Unit structure to ensure the capability to withstand and survive launch and ascent loads. The effects of any thermal inputs shall be reflected in the analyses as appropriate. The results of these analyses shall be summarized in a Contractor format Mechanical Analyses Report that will be provided to the NASA/GSFC COTR for review.

5.0 HARDWARE MANUFACTURE

5.1 S-BAND TRANSPONDER

The Contractor shall manufacture and test one Protoflight Unit S-Band Transponder and one Flight S-Band Transponder to meet the requirements of the Lunar Reconnaissance Orbiter Project S-Band Telemetry, Tracking and Command Subsystem Performance Specification (431-SPEC-000121).

5.2 S-BAND DIPLEXER

The Contractor shall procure and test three Flight S-Band RF Band-Reject Filter / Diplexer assemblies to meet the requirements of the Lunar Reconnaissance Orbiter Project S-Band Telemetry, Tracking and Command Subsystem Performance Specification (431-SPEC-000121). The Contractor must obtain the concurrence of the NASA/GSFC COTR before selecting a diplexer for procurement.

5.3 S-BAND RF TRANSFER SWITCH

The Contractor shall procure and test two Flight S-Band RF Transfer Switch assemblies to meet the requirements of the Lunar Reconnaissance Orbiter Project S-Band Telemetry, Tracking and Command Subsystem Performance Specification (431-SPEC-000121). The Contractor must obtain the concurrence of the NASA/GSFC COTR before selecting a RF Transfer Switch for procurement.

5.4 S-BAND DIRECTIONAL COUPLER

The Contractor shall procure and test one Flight S-Band RF Directional Coupler assembly to meet the requirements of the Lunar Reconnaissance Orbiter Project S-Band Telemetry, Tracking and Command Subsystem Performance Specification (431-SPEC-000121).

5.5 INTEGRATED SUBSYSTEM ASSEMBLY

The Contractor shall procure or manufacture the necessary cables, harness and interconnects to assemble the components of the TT&C Subsystem into an integrated Protoflight TT&C Subsystem and a Flight TT&C Subsystem. The Contractor shall integrate the components of Sections 5.1, 5.2, 5.3, 5.4, and 5.5 into an integrated TT&C Subsystem Assembly. The Contractor shall test the integrated TT&C Subsystem assembly for compliance with all component requirements.

5.6 CONNECTOR SAVERS

Flight Units shall be tested with connector savers to minimize mates and demates. Connector savers shall be delivered with each Flight Unit.

5.7 SUPPORTING HARDWARE

The Contractor shall provide the following supporting hardware:

- One set of the mating half of the external connectors for each delivered Unit, plus two additional sets per contract delivery schedule
- Electrostatic Discharge (ESD) flight protective caps, as applicable
- Closeout caps for test connectors

The Contractor shall provide two shipping containers, which will be used to ship the TT&C Subsystems from the vendor to GSFC. The shipping containers shall have temperature monitors and recorders, humidity recorders, and equipped with shock recorders. The Protoflight TT&C Subsystem shall use the same shipping containers as the Flight TT&C Subsystem. The design should be compliant with the Lunar Reconnaissance Orbiter Mechanical Interface Control Drawing Guidelines Handbook (431-HDBK-000093).

The Contractor shall also supply a drill template for the mounting holes.

5.8 GROUND SUPPORT EQUIPMENT

The Contractor shall provide GSE to support integration and test (I&T) activities at the Orbiter level. GSE includes:

- Transport caps
- Transponder Test Controller

6.0 QUALITY ASSURANCE

6.1 GENERAL REQUIREMENTS

6.1.1 Quality Assurance Plan/Manual

The Contractor shall implement a Quality Management System that meets the intent of the requirements of American National Standards Institute (ANSI)/International Organization for Standardization (ISO)/American Society for Quality (ASQ) Q9001 (1994 or 2000 version) or equivalent. The Contractor shall submit a Quality Management Plan to GSFC, detailing how the requirements in Sections 6, 7, and 8 will be met. GSFC shall be notified of any changes to the QA program.

6.1.2 Surveillance of the Contractor

The work activities and operations of the contractor, subcontractors, and suppliers are subject to evaluation, review, survey, and inspection by GSFC representative.

The Contractor shall provide the GSFC representative with documents, records, equipment, and workings areas within their facilities that are required by the representative to perform their overview activities.

6.1.2.1 Government Source Inspection

The Government may elect to perform inspections at a supplier's plant. The following statement shall be included on all contract or subcontract documents: "All work on this order is subject to inspection and test by the Government at any time and place".

The Government QA Representative who has been delegated NASA QA functions on this procurement shall be notified immediately upon contractor receipt of any supplier/ subcontractor orders. The Government QA Representative shall also be notified 48 hours in advance of the time that articles or materials are ready for inspection or test.

6.1.2.2 Contractor Source Inspection

The Contractor shall ensure that its contract or subcontract documents impose the applicable requirements on subcontractors and other suppliers. The subcontractor and other suppliers shall in turn impose the requirements on their procurement sources.

The Contractor shall perform source inspection at the subcontractor's or supplier's facilities in accordance with the contract or subcontract documentation or when one or more of the following conditions exist:

In process, end item controls, or tests that are destructive in nature prevent the developer from verifying quality after delivery to the developer's facility.

It is not feasible or economical for the contractor to determine the quality of procured articles solely by inspections or tests performed at the contractor's facility.

Qualification tests are to be performed by the subcontractor or supplier.

Products are shipped directly from the source to NASA, by-passing the Contractor's inspection facilities.

6.1.2.3 Government Mandatory Inspection Points

The Government or its representative will perform the following Government Mandatory Inspection Points (MIP) listed below. The Government may request additional MIPs if a specific process prohibits inspection at a later time. MIPs are reviewed at the TIM and are mutually agreed upon prior to production under this contract.

MIPs to be performed:

- Inspect 100% solder
- Inspect 100% crimps
- Inspect 100% conformal coating, staking, and potting
- Rework Inspection
- Pre-closure Inspection
- Pre-Shipment Inspection / Data Review

6.1.3 Configuration Management

The Contractor's CM system (available for review on request) shall control the design and hardware/software by means of drawings, specifications, and other documents and shall ensure all applicable changes are reviewed in a systematic manner to determine the validity and impact on performance, schedule, and cost. The Contractor's CM system shall have a change classification and impact assessment process that ensures Class I changes are forwarded to the CO for approval prior to release/incorporation. Class I changes are defined as changes that affect form, fit, function, external interfaces, or requirements as stated within this document and the Lunar Reconnaissance Orbiter Project S-Band Telemetry, Tracking and Command Subsystem Performance Specification (431-SPEC-000121).

All other changes are considered to be Class II changes and shall be controlled and dispositioned by the contractor. All Class II changes shall be provided monthly to the COTR for review purposes. NASA/GSFC reserves the right to review all Class II changes for technical content to ensure the proper classification has been assigned. Any flight item that is found to be non-compliant with the quality, workmanship and performance requirements of the contract shall be dispositioned via a waiver or MRB, unless the affected item is reworked to restore compliance or is replaced with a fully compliant item. The Contractor shall submit Waivers to the COTR for final approval.

A Contractor QA Representative shall be a member of the Configuration Control Board (CCB). The QA activities shall be defined in the Contractor's Configuration Management Plan and described in detail in the Quality Assurance Plan in accordance with the Lunar Reconnaissance Orbiter Mission Assurance Requirements (431-RQMT-000174). Related portions of the plans shall be cross-referenced.

All Contractor's CM related activities and deliveries shall be done in accordance to the Lunar Reconnaissance Orbiter Project Configuration Management Procedure (431-PROC-000179).

The Contractor shall provide a Data Management Plan, which shall be compliant with the Lunar Reconnaissance Orbiter Data Management Procedure (431-PROC-000180).

6.1.4 Anomaly Reporting

Reporting of hardware anomalies to the NASA/GSFC COTR shall begin no later than the first power-on acceptance testing or the first cycle/actuation for mechanical items at the start of acceptance testing. The NASA/GSFC COTR shall be notified within 24 hours of each anomaly occurring during acceptance testing.

The Contractor's processes for review, disposition and approval of anomaly reports shall be described in their quality plan/manual or provided as a supplement document. In addition, the Contractor's anomaly reporting document shall describe the members of the MRB and Failure Review Board (FRB). The MRB and FRB shall include LRO GSFC participation. These processes shall ensure that positive corrective action has been taken to preclude recurrence and that appropriate audits and tests are performed to verify the implementation of the corrective action.

The Contractor shall routinely inform the LRO QA Representative of MRB and FRB meeting schedules and agendas with sufficient notice to permit LRO Project participation if desired by LRO.

At the Contractor's facility, NASA/Government representatives may participate in MRB/FRB activities as deemed appropriate by Government management or contract.

The NASA/GSFC COTR reserves disapproval rights on MRB and FRB decisions. To assure process consistency, the contractor shall provide the LRO Project access to their LRO anomaly reporting database. The project office shall be informed of decisions on MRBs and FRBs via e-mail or by mail.

The Contractor shall provide, as part of the monthly report, a list of all open anomaly reports and a separate list of the anomaly reports closed during the month. For each reported anomaly or nonconformance, there shall be a report that documents the investigation and engineering analysis needed to determine the cause and corrective actions to disposition the nonconformance, and identify any closed problem reports that do not have a definitive cause or corrective action. Reports shall be submitted to the NASA/GSFC COTR for review and approval of the disposition.

The supplier shall establish and maintain documented procedures to ensure product that does not conform to specific requirements is prevented from unintended use or installation. This control shall provide for identification, documentation, evaluation, segregation (when practical), disposition of nonconforming product, and for notification to the functions concerned.

6.2 SYSTEM SAFETY REQUIREMENTS

The Contractor shall supply detailed descriptions of the design, test, operation and inspection requirements for all flight hardware and materials, GSE, and their interfaces necessary for a valid identification, assessment, control and mitigation of documented hazards. This includes

technical information concerning hazardous and safety critical equipment, systems, operations, handling and materials. For all identified hazards, the Contractor shall also document hazard controls, verifications and tracking methods.

The Contractor shall provide technical support to the LRO Project for safety working group and technical meetings as necessary in conjunction with TIMs.

6.3 RELIABILITY REQUIREMENTS

The Contractor shall prepare and conduct the following set of reliability analyses.

6.3.1 Failure Modes and Effects Analysis

The Contractor shall perform a Failure Modes and Effects Analysis (FMEA) in accordance with the Procedures for Performing an FMEA (MIL-STD-1629). The FMEA shall identify failures at the functional level and address attendant consequences. This analysis shall be provided to the NASA/GSFC COTR for review. Preliminary and final reports shall be provided in accordance with the Lunar Reconnaissance Orbiter S-Band Telemetry, Tracking and Command Subsystem Deliverable Items List and Schedule (431-LIST-000304).

6.3.2 Electrical, Electronic, and Electromechanical Parts Stress Analyses

The Contractor shall perform parts stress analyses on EEE parts and devices as employed in the circuit designs of the Flight Item to certify conformance with the de-rating requirements of EEE parts. The analyses shall be documented, and justification shall be included for all applications that do not meet the de-rating criteria. The Contractor shall use the Instructions for EEE Parts Selection, Screening, Qualification, and De-rating (EEE-INST-002) NASA document to establish criteria. Contractor de-rating guidelines may be considered in place of EEE-INST-002 guidelines but shall be submitted for approval. This analysis shall be provided to the NASA/ GSFC COTR for review. Preliminary and final reports shall be provided in accordance with the Lunar Reconnaissance Orbiter S-Band Telemetry, Tracking and Command Subsystem Deliverable Items List and Schedule (431-LIST-000304).

6.3.3 Worst-Case Analyses

The Contractor shall perform worst-case parameter analyses on performance critical or functional critical components for which excessive operating variations could compromise mission performance. The Contractor shall identify the worst-case analyses planned to assure the design meets critical performance and life requirements. Adequate margins in electronic circuits, optics, electromechanical devices, or other mechanical items (mechanisms) can be verified by analysis, testing or both. When verification by analysis is used, the analyses shall consider all parameters at worst-case limits and worst-case environmental conditions for the parameter or operation being evaluated. Similarly, when verification by testing is used, the testing shall be conducted to provide as direct a measure as possible of the critical performance or function while the element is subjected to worst-case parameter variations. Elements that may warrant worst-case analysis may include: control loops that require adequate phase and gain margin to operate properly, sensitive analog circuitry, power supply or switching circuitry, motor and actuator systems, electro-mechanical elements that require torque margin to operate over life

and environmental variations. Preliminary and final reports shall be provided in accordance with the Lunar Reconnaissance Orbiter S-Band Telemetry, Tracking and Command Subsystem Deliverable Items List and Schedule (431-LIST-000304).

Worst case analysis must be performed at a minimum where circuit and EEE parts used in the circuit do not meet or exceed derating criteria as specified in EEE-INST-002. Worst case analysis is not required where design margin can be demonstrated by analysis.

6.3.4 Limited-Life Items

The Contractor shall identify and manage limited-life items. Limited-life items include all hardware that is subject to degradation because of limited shelf life or expected operating times or cycles such that their expected useful life is less than twice the required life when fabrication, test, storage, and mission operation are combined. Preliminary and final reports shall be provided in accordance with the Lunar Reconnaissance Orbiter S-Band Telemetry, Tracking and Command Subsystem Deliverable Items List and Schedule (431-LIST-000304).

The LRO Project COTR shall approve the use of an item whose expected life is less than twice the mission design life.

6.4 GROUND SUPPORT EQUIPMENT

Mechanical and electrical GSE and associated software that directly interfaces with flight deliverable items shall be assembled and maintained to mitigate potential risk to flight hardware. Parts and materials selection and reporting requirements are exempted as long as deliverable flight item contamination requirements are not compromised. However, all GSE interfaces to flight hardware shall be flight quality (i.e., connectors, baseplates, etc.).

6.5 DESIGN VERIFICATION REQUIREMENTS

6.5.1 Verification Requirements

The Contractor shall implement a program to verify all requirements specified in the Lunar Reconnaissance Orbiter S-Band Telemetry, Tracking and Command Subsystem Performance Specification (431-SPEC-000121).

The Contractor shall provide a verification matrix defining the method of verification for each specific requirement of this contract. Verification methods shall include:

Inspection: Designated as (I) and represents inspection of the physical hardware by a customer appointed qualified inspector for compliance.

Analysis: Designated as (A) and represents documentation of performance or function through detailed analysis using all applicable tools and techniques.

Test: Designated as (T) and represents a detailed test of performance and/or functionality throughout a properly configured test setup where all critical data taken during the test period is captured for review.

In-process production evaluation tests and environmental stress screening tests shall also be considered to be verification tests.

6.5.2 Analysis/Trending/Reporting Of Test Data

The Contractor shall properly record, maintain and analyze test information during the normal test program to assess performance and flight worthiness and to aid in the identification and analysis of flight hardware failures and problems.

The Contractor shall also perform trend analyses to track measurable parameters that relate to performance stability and repeatability. Selected parameters shall be monitored for trends starting at component acceptance testing and continuing through the system I&T phases. These parameters will be compiled in a Trended Parameters List (TPL).

The reports will be delivered as part of the Data Delivery Package and presented at formal technical reviews as appropriate.

6.5.3 Demonstration of Failure-Free Operation

The Contractor shall have demonstrated a period of 100 hours of contiguous failure-free operation for each Unit prior to delivery.

6.6 WORKMANSHIP STANDARDS AND PROCESSES

6.6.1 Workmanship: Use of Alternate Workmanship Standards

GSFC recognizes that the Contractor may have an established workmanship program equivalent to the specific standards cited herein. In these instances, the contractor may use existing standards upon review and approval by the LRO Project COTR. It must be established that the developer's workmanship program fully encompasses the specific requirements of this section. It is the Contractor's responsibility to list all deviations from the baseline workmanship standards and to provide data supporting their position/rationale.

6.6.2 Training and Certification of Contractor Personnel

All personnel performing work on flight hardware requiring a prerequisite set of skills and competency shall be certified as having completed the required training, appropriate to their involvement.

6.6.3 Hardware Handling, Cleaning And Packaging

Qualified personnel in accordance with approved procedures that address cleaning, handling, packaging, tent enclosures, shipping containers, bagging, and purging shall perform the handling of flight hardware. Compatible packaging shall be selected so that hardware is not contaminated or otherwise degraded during shipping or storage. All personnel working on flight hardware shall be certified as having completed the required training and competency certifications prior to handling any flight hardware. This includes, but is not limited to, workmanship, clean room and ESD awareness courses.

6.6.4 Electrostatic Discharge Control Requirements

The Contractor shall document and implement an ESD Control Program suitable to protect the most ESD-sensitive instrument components at all levels of assembly and integration in accordance with the requirements of ANSI/ESD S20.20 or NASA-STD-8739.7.

All personnel who manufacture, inspect, test or otherwise process electronic hardware or who require unescorted access into ESD-protected areas shall be certified as having completed the required training, appropriate to their involvement prior to handling any electronic hardware.

6.6.5 Workmanship Requirements For Printed Circuited Boards, Soldered Assemblies, Harnessing, and Fiber Optics

The following workmanship standards shall apply to printed circuit boards, soldered assemblies, harnessing, and fiber optics.

6.6.5.1 Requirements for Printed Wiring Boards

a) Printed Wiring Board (PWB) Design:

Space Flight PWB designs shall not include features that prevent the finished board(s) from complying with the Class 3 Requirements of the appropriate manufacturing standard (e.g., specified plating thickness, internal annular ring dimensions, etc.).

IPC-2221, Generic Standard on Printed Board Design (for non-critical ground support equipment only as defined in S312-P-003 paragraph 1.4)

IPC-2222, Sectional Design Standard for Rigid Organic Printed Boards (for non-critical ground support equipment only as defined in S312-P-003 paragraph 1.4)

IPC-2223, Sectional Design Standard for Flexible Printed Boards

IPC-D-275, Design Standard for Rigid Printed Boards and Rigid Printed Board Assemblies

b) PWB Manufacture:

GSFC S312-P-003, Procurement Specification for Rigid Printed Boards for Space Applications and Other High Reliability Uses (the use of this procurement specification is critical in the procurement of "Flight" and "Critical Ground Support" boards)

IPC-6011, Generic Performance Specification for Printed Boards

IPC-6012, Qualification and Performance Specification for Rigid Printed Boards

IPC-6013, Qualification and Performance Specification for Flexible Printed Boards

IPC-A-600, Acceptability of Printed Boards

The Contractor shall provide PWB coupons to the LRO COTR, or to a GSFC-approved laboratory for evaluation. PWB coupon approval shall be obtained from COTR or a GSFC approved laboratory prior to population of flight PWBs.

6.6.5.2 Workmanship Requirements

The following workmanship requirements shall apply:

Conformal Coating and Staking: NASA-STD-8739.1, Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies;

Surface Mount Technology (SMT): NASA-8739.2, Workmanship Standard for Surface Mount Technology;

Hand Soldering Assemblies: NASA-STD-8739.3, Soldered Electrical Connection

Crimping, Wiring, and Harnessing: NASA-STD-8739.4, Crimping, Interconnecting Cables, Harnesses, and Wiring;

Fiber Optics: NASA-STD-8739.5, Fiber Optic Terminations, Cable Assemblies, and Installation

6.6.5.3 New or Advanced Packaging Technologies

Workmanship requirements or standards, including design, qualification, and acceptance requirements, specified by the Contractor for advanced packaging technologies, such as multi-chip modules (MCMs), stacked memories, chip on board, column-grid arrays (CGA) or ball grid arrays (BGA), shall be submitted to the NASA/GSFC COTR for review and approval prior to use.

Each Non-Standard Process document shall address process control, fabrication, inspection, training, and acceptance and rejection criteria. Test data and evaluation records shall be submitted as part of the process support for approval, as applicable.

6.7 ELECTRICAL, ELECTRONIC, AND ELECTROMECHANICAL PARTS REQUIREMENT

6.7.1 General

Flight Unit parts shall be selected and processed in accordance with the requirements as described in the Instructions for EEE Parts Selection, Screening, Qualification, and Derating (EEE-INST-002). All application notes in EEE-INST-002 will apply.

The minimum acceptable EEE part grade available for Flight Unit use on LRO is Class 2 with 100% Particle Impact Noise Detection (PIND) screening for cavity bodied devices and a sample Destructive Physical Analysis (DPA). This assumes that the radiation hardness requirements and system reliability goals are also being met. This would include parts costs, test costs, risk of test failures and reliability differences between both classes. The Contractor shall maintain an EEE Parts Identification List and shall review proposed parts with the NASA/GSFC COTR. Preliminary and final reports shall be provided in accordance with the Lunar Reconnaissance Orbiter S-Band Telemetry, Tracking and Command Subsystem Deliverable Items List and Schedule (431-LIST-000304).

6.7.2 Custom Devices

In addition to the applicable requirements of EEE-INST-002, custom microcircuits, hybrid microcircuits, MCM, Application-Specific Integrated Circuit (ASIC) and other non-standard application unique devices planned for Flight Unit shall be subjected to a parts-level design review (with GSFC participation). The design review shall address, at a minimum, de-rating of elements, method used to certify acceptable reliability, assembly and materials processes, methods for assuring adequate thermal matching of materials, and screening and qualification requirements.

6.7.3 Plastic Encapsulated Microcircuits

The use of Plastic Encapsulated Microcircuits (PEMs) is discouraged in the Flight Unit. However, when use is necessary to achieve unique requirements that cannot be found in hermetic high reliability microcircuits, plastic encapsulated parts, must meet the requirements of the Instructions for EEE Parts Selection, Screening, Qualification, and Derating (EEE-INST-002). All PEM(s) require NASA/GSFC COTR review and concurrence. PEM usage shall be presented at the Design Conformance Review and TIMs, as applicable.

PEMs usage will be considered on a case by case basis. Approval will depend on the heritage of the part, part usage history, space flight history, testing performed by the supplier/manufacturer, assembly environmental stress screening, and available test data.

6.7.4 Radiation Hardness

All Flight Unit parts shall be selected to meet their intended application in the on-orbit LRO radiation environment as defined in the Lunar Reconnaissance Orbiter S-Band Telemetry, Tracking and Command Subsystem Performance Specification (431-SPEC-000121). The radiation environment consists of two separate effects: total ionizing dose (TID) and single-event effects (SEE). The Contractor shall document the radiation hardness assessment for each part with respect to both effects and include this assessment as part of the CDR Presentation Package. Test plans and reports for parts that require radiation testing shall be submitted to the NASA/GSFC COTR for review.

6.7.5 Parts Age Control

Parts more than five years old require LRO COTR concurrence. Contractors shall present justification with inspection and test requirements.

6.7.6 Government Industry Data Exchange Program Alerts and Problem Advisories

Contractors shall keep sufficient selection and usage records for all flight parts and materials adequate to determine applicability of any issued Government Industry Data Exchange Program (GIDEP) alerts relevant to items used on LRO. The Contractor shall review and disposition all GIDEP Alerts for relevancy and impact. In addition, the Contractor shall review and disposition any NASA Alerts and Advisories provided to the developer by the LRO Project. Alert applicability, impact, and corrective actions shall be documented and status provided to the LRO Project on a monthly basis.

6.7.7 Reuse of Parts and Materials

EEE parts and materials, which have been installed in an assembly, and removed for any reason, shall not be used again for flight.

6.7.8 Part Notification of Failure

The contractor shall provide failure-reporting data to NASA/GSFC COTR within 72 hours of part failure determination.

6.8 MATERIALS, PROCESSES AND LUBRICATION REQUIREMENTS

6.8.1 Materials Selection Requirements

To qualify material for flight use, the material must have a satisfactory flight heritage relevant to LRO requirements or meet the following applicable selection criteria as defined herein for:

- Vacuum outgassing
- Stress corrosion cracking (SCC)
- Lubrication requirements
- Manufacturing process selection
- Fastener integrity

The Contractor shall create and maintain a Materials and Processes (M&P) Identification List and shall review proposed materials and processes with the LRO GSFC COTR. An As-Built Materials List (ABML) shall be included as part of the end item data package. Preliminary and final reports shall be provided in accordance with the Lunar Reconnaissance Orbiter S-Band Telemetry, Tracking and Command Subsystem Deliverable Items List and Schedule (431-LIST-000304).

Pure Tin, Zinc, and Cadmium are not acceptable for flight use.

6.8.2 Vacuum Outgassing of Polymeric Materials

Only materials that have a total mass loss (TML) less than 1.00% and a collected volatile condensable mass (CVCM) less than 0.10% shall be approved for use in a vacuum environment. Material vacuum outgassing shall be determined in accordance with the Standard Test Method for Total Mass Loss and Collected Volatile, Condensable Materials for Outgassing (ASTM E-595). If a material exceeds these maximum limits, the contractor shall be required to either replace with a compliant material or bring it into compliance via a vacuum bakeout, or to submit a Material Usage Agreement (MUA) for its usage. Preliminary and final reports shall be provided in accordance with the Lunar Reconnaissance Orbiter S-Band Telemetry, Tracking and Command Subsystem Deliverable Items List and Schedule (431-LIST-000304).

6.8.3 Stress Corrosion Cracking of Inorganic Materials

Materials used in structural applications shall be highly resistant to SCC as specified in the Selection of Metallic Materials for Stress Corrosion Cracking Resistance (MSFC-STD-3029). A MUA and a SCC evaluation form shall be submitted, contractor format acceptable, for each material usage that does not comply with the Selection of Metallic Materials for Stress Corrosion Cracking Resistance (MSFC-STD-3029) requirements.

6.8.4 Lubrication Systems

The Contractor's material list shall include lubrication usage. Lubricants shall be selected for use with materials on the basis of flight heritage and valid test results that confirm the suitability of the composition and the performance characteristics for each specific application, including compatibility with the anticipated environment and contamination concerns.

All lubricated mechanisms shall be life tested unless it can be established and documented that a valid flight heritage exists to an identical mechanism used in an identical flight application or to an identical mechanism that has been separately qualified by suitable life testing.

6.8.5 Process Selection Requirements

Materials and manufacturing process information shall be provided on the material list.

6.8.6 Fasteners

The contractor shall comply with the procurement and test requirements for flight hardware and critical GSE fasteners contained in the Goddard Space Flight Center Fastener Integrity Requirements Procedures and Guidelines (541-PG-8072.1.2). Traceability shall be maintained for every fastener lot.

6.8.7 Materials Procurement Requirements

Raw materials purchased by the contractor and its developers shall be accompanied by a Certificate of Compliance and, where applicable, the results of nondestructive, chemical and physical tests. When requested, this information shall be made available to the NASA/GSFC COTR for review.

6.8.8 Dissimilar Metals

To avoid electrolytic corrosion, dissimilar metals should not be used in direct contact unless protection against corrosion has been provided in accordance with the Dissimilar Materials (MIL-STD-889). Variances from this policy must be submitted to the government for approval.

7.0 CONTAMINATION CONTROL REQUIREMENTS

The Contractor shall establish the specific cleanliness requirements to minimize performance degradation and delineate the approaches to meet the LRO Project requirements.

7.1 THERMAL VACUUM BAKEOUTS

Thermal vacuum bake-out of the S-Band Transponder shall be performed before delivery. The parameters of such bakeouts (e.g., temperature, duration, outgassing requirements, and pressure) are specified in the Lunar Reconnaissance Orbiter S-Band Telemetry, Tracking and Command Subsystem Performance Specification (431-SPEC-000121).

A quartz crystal microbalance (QCM) or temperature controlled quartz crystal microbalance (TQCM) shall be incorporated during all thermal vacuum bakeouts. The QCM shall provide the outgassing rate data during the bakeout. This data shall be recorded and provided in the data package.

Although the thermal vacuum test is normally used for a final bakeout opportunity [usually in the last hot cycle], the individual components should be fully cured and baked out before thermal vacuum testing to minimize the length of time spent in the chamber.

7.2 EXTERNAL CLEANLINESS

All exterior hardware cleanliness shall be verified to be 450A, as described in the Product Cleanliness Levels and Contamination Control Program (IEST-STD-CC1246), upon delivery to GSFC.

8.0 HANDLING, STORAGE, PACKAGING, PRESERVATION, AND DELIVERY

Products shall be stored, preserved, marked, labeled, packaged, and packed to prevent loss of marking, deterioration, contamination, excessive condensation and moisture, or damage during all phases of the program. Stored and stocked items shall be controlled in accordance with documented procedures and be subject to quality surveillance.

The Contractor is responsible for providing an acceptable shipping container that protects the hardware appropriately.

While in a shipping container, the S-Band Transponder shall be wrapped in a non-ESD-generating vapor barrier with redundant maximum humidity indicators.

The shipping container shall also include shock and humidity indicators and shall be capable of prolonged shipping conditions. The Contractor shall document what action NASA/GSFC is to take if the sensors are tripped when hardware arrives at the NASA/GSFC receiving area. A copy of this document shall be included with shipping documentation.

By executing the act of product shipment, the supplier certifies that the product complies with all contract requirements. Prior to shipping, QA personnel shall ensure that:

- Fabrication, inspection, and test operations have been completed and accepted.
- All products are identified and marked in accordance with requirements.
- The accompanying documentation (developer's shipping and property accountable form) has been reviewed for completeness, identification, and quality approvals.
- Evidence exists that preservation and packaging are in compliance with requirements.
- Packaging and marking of products, as a minimum comply with Interstate Commerce Commission rules and regulations and are adequate to ensure safe arrival and ready identification at their destinations.
- The loading and transporting methods are in compliance with those designated in the shipping documents.
- Integrity seals are on shipping containers and externally observable shock or humidity monitors do not show excessive environmental exposure.
- In the event of unscheduled removal of a product from its container, the extent of re-inspection and retest shall be as authorized by NASA or its representative.
- Special handling instructions for receiving activities, including observation and recording requirements for shipping-environment monitors are provided where appropriate.

The Contractor's QA organization shall verify prior to shipment that the above requirements have been met and shall sign off appropriate shipping documents to provide evidence of this verification. The Contractor shall ship Freight On Board (FOB) to Greenbelt, Maryland. The Contractor will be held responsible for any damaged incurred during shipment.

Appendix A. Abbreviations and Acronyms

Abbreviation/ Acronym	DEFINITION
A	Analysis
ABML	As-Built Material List
ANSI	America National Standard Institute
ASIC	Application-Specific Integrated Circuit
ASQ	American Society for Quality
BGA	Ball Grid Arrays
CCB	Configuration Control Board
CDR	Critical Design Review
CGA	Column-Grid Arrays
CM	Configuration Management
CO	Contracting Officer
COTR	Contracting Officer's Technical Representative
CVCM	Collected Volatile Condensed Mass
DPA	Destructive Physical Analysis
EEE	Electrical, Electronic, and Electromechanical
ESD	Electro Static Discharge
EU	Engineering Unit
FMEA	Failure Mode and Effect Analysis
FOB	Freight on Board
FRB	Failure Review Board
GEVS	General Environmental Verification Specification
GIDEP	Government Industry Data Exchange Program
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
I	Inspection
I&T	Inspection and Test
INST	Instrument
ISO	International Organization for Standardization
LRO	Lunar Reconnaissance Orbiter
M&P	Materials and Processes
MCM	Multi-Chip Modules
Mil	Military
MIP	Mandatory Inspection Point
MRB	Material Review Board
MSFC	Marshall Space Flight Center
MUA	Material Usage Agreement
NASA	National Aeronautics and Space Administration
PDR	Preliminary Design Review
PEM	Plastic Encapsulated Microcircuit

Abbreviation/ Acronym	DEFINITION
PER	Preliminary Environmental Review
PIND	Particle Impact Noise Detection
PSR	Pre-Shipment Review
PWB	Printed Wiring Board
QA	Quality Assurance
QCM	Quartz Crystal Microbalance
RQMT	Requirement
SCC	Stress Corrosion Cracking
SEE	Single-Event Effect
SINDA	System Improved Numerical Differencing Analyzer
SMT	Surface Mount Technology
SOW	Statement of Work
STD	Standard
T	Test
TID	Total Ionizing Dose
TIM	Technical Interchange Meeting
TML	Total Mass Loss
TPL	Trended Parameters List
TQCM	Temperature-controlled Quartz Crystal Microbalance

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Lunar Reconnaissance Orbiter Project

S-Band Telemetry, Tracking & Command Subsystem Performance Specification

February 8, 2006

National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland

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1.0 SCOPE

This specification establishes the design and performance requirements for the S-Band Telemetry, Tracking and Command (TT&C) Subsystem, to be used on the spacecraft bus for the Lunar Reconnaissance Orbiter (LRO) mission. S-Band TT&C Subsystem provides the primary means to transmit spacecraft state of health telemetry to the ground and to receive spacecraft command from the ground. The S-Band TT&C Subsystem also provides the ability to perform radiometric measurement of spacecraft range and range-rate (Doppler). The S-Band TT&C Subsystem operates in the near-Earth Unified S-Band (USB).

2.0 DOCUMENTATION AND DEFINITIONS

2.1 APPLICABLE DOCUMENTS

The following documents form part of this specification to the extent specified herein or as general guidelines. In the event of a conflict between this specification and other referenced documents, the following order of precedence applies:

431-ICD-000374	Lunar Reconnaissance Orbiter S-Band Transponder Electrical Interface Control Document
431-ICD-000375	Lunar Reconnaissance Orbiter S-Band Transponder Mechanical Interface Control Document
431-SOW-000303	S-Band Telemetry, Tracking & Command Subsystem Statement of Work
431-RQMT-000174	Lunar Reconnaissance Orbiter Mission Assurance Requirement
GSFC-STD-7000	General Environmental Verification Specification (GEVS) for GSFC Flight Programs and Projects

2.2 REFERENCE DOCUMENTS

431-SPEC-000008	Lunar Reconnaissance Orbiter Project Electrical Systems Specification
431-SPEC-000013	Lunar Reconnaissance Orbiter Project Power Subsystem Electronics Specification
431-SPEC-000020	Lunar Reconnaissance Orbiter Radiation Environment Specification
431-SPEC-000091	Lunar Reconnaissance Orbiter Thermal System Specification
431-REF-000273	Single Event Effect Criticality Analysis (SEECA)
431-RQMT-000045	Radiation Requirements for the Lunar Reconnaissance Orbiter
565-PG-8700.2.1	Design and Development Guidelines for Spaceflight Electrical Harnesses
CCSDS 101.0-B-6	Consultative Committee for Space Data Systems Telemetry Channel Coding Blue Book
DSN 810-5	DSN/Flight Project Interface Design Handbook
EEE-INST-002	Instructions for EEE Parts Selection, Screening, Qualification, and Derating
MIL-C-39012	Connectors, Plug, Electrical, Coaxial, Radio Frequency, (series N (cabled), Pin Contact, Class 2)
MIL-STD-461	EMI/EMC Requirements Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference
MIL-STD-462	EMI/EMC Testing Methods
NASA-HDBK-4001	Electrical Grounding Architecture for Unmanned Spacecraft
NASA-HDBK-4002	Avoiding Problems Caused by Spacecraft On-Orbit Internal Charging Effects
RTCA-DO160E	Environmental Conditions and Test Procedures for Airborne Equipment
TIA/EIA-422	Electrical Characteristics of Balanced Voltage Digital Interface Circuits (formerly known as RS-422)

TP2361	Design Guidelines for Assessing and Controlling Spacecraft Charging Effects
N/A	Manual of Regulations and Procedures for Federal Radio Frequency Management

3.0 REQUIREMENTS

This section specifies the functional, performance, interface, logistic, quality factor, and design requirements for the S-band TT&C Subsystem assembly.

3.1 DESCRIPTION

The LRO Communication System, depicted in Figure 3-1, consists of an S-Band Tracking, Telemetry and Command (TT&C) Subsystem, a Ka-Band High Rate Transmitter, a High Gain Antenna (HGA) System, and a Low Gain Antenna (LGA) System, as well as the necessary passive components and cables. The LRO S-Band TT&C Subsystem, depicted in Figure 3-2, consists of one Spaceflight Tracking and Data Network (STDN)-compatible transponder, an S-band RF Switch, and the RF paths to and from the TT&C omnidirectional antennas and the S-band feed on the LRO HGA which includes a 6 decibel (dB) coupler.

The radio frequency (RF) path to/from the TT&C low gain antennas consists of a band-reject filter (BRF)/diplexer, a RF combiner, two low gain antennas, and their associated RF coaxial cable network. The RF transmit path to the HGA consists of a BRF/diplexer and the S-band feed to the HGA. The HGA RF receive path is coupled to the LGA RF receive path through the combination of a 6 dB directional coupler. In this manner, the receive path is always available through both HGA and LGAs, while the transmit path is selectable through the RF switch. 20dB directional couplers to test ports are used in both the omnidirectional and HGA signal paths for test and verification during subsystem and spacecraft integration and test (I&T).

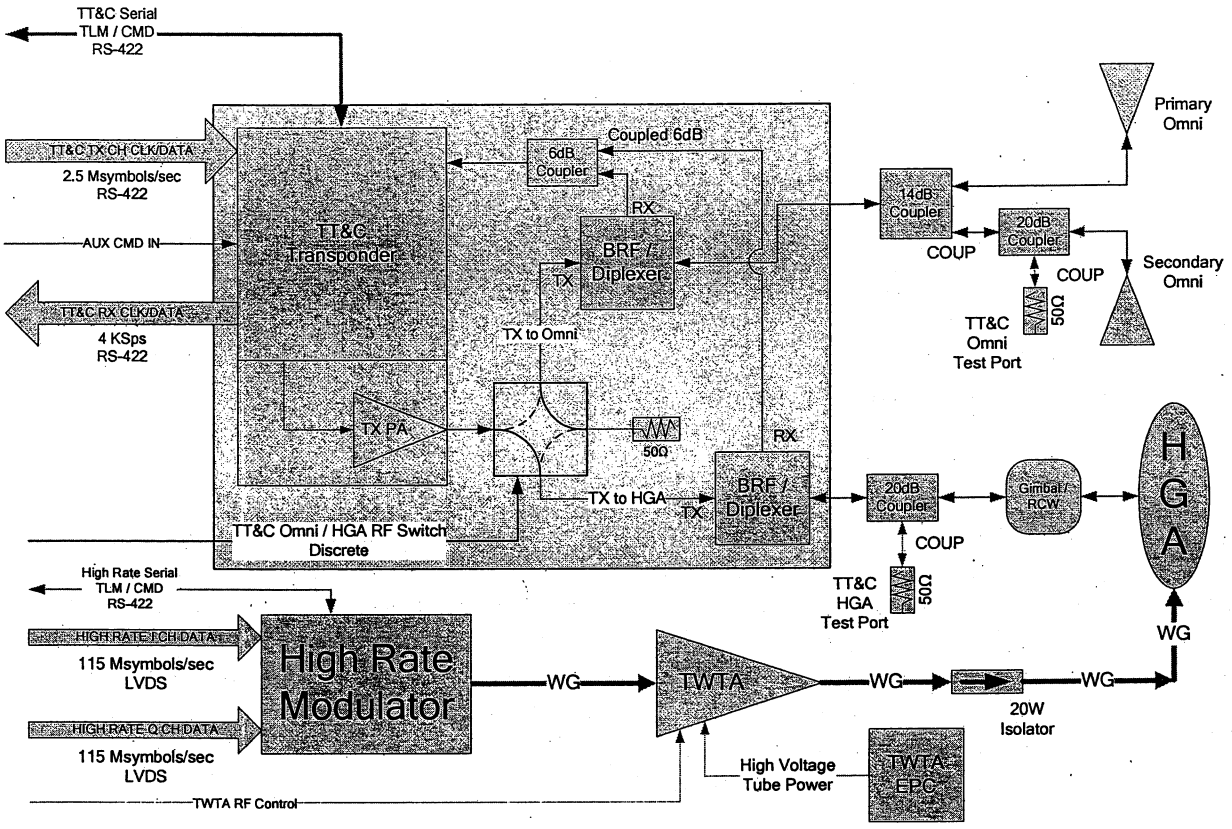


Figure 3-1. LRO Communication System Block Diagram

The diplexers allow the transponder's receiver and transmitter to connect to a common antenna port which in turn connects to the appropriate RF network for each antenna system. The diplexers will also include band pass and band reject filters in the transmit channel to suppress any receive signal component in the output of the transmitting power amplifier.

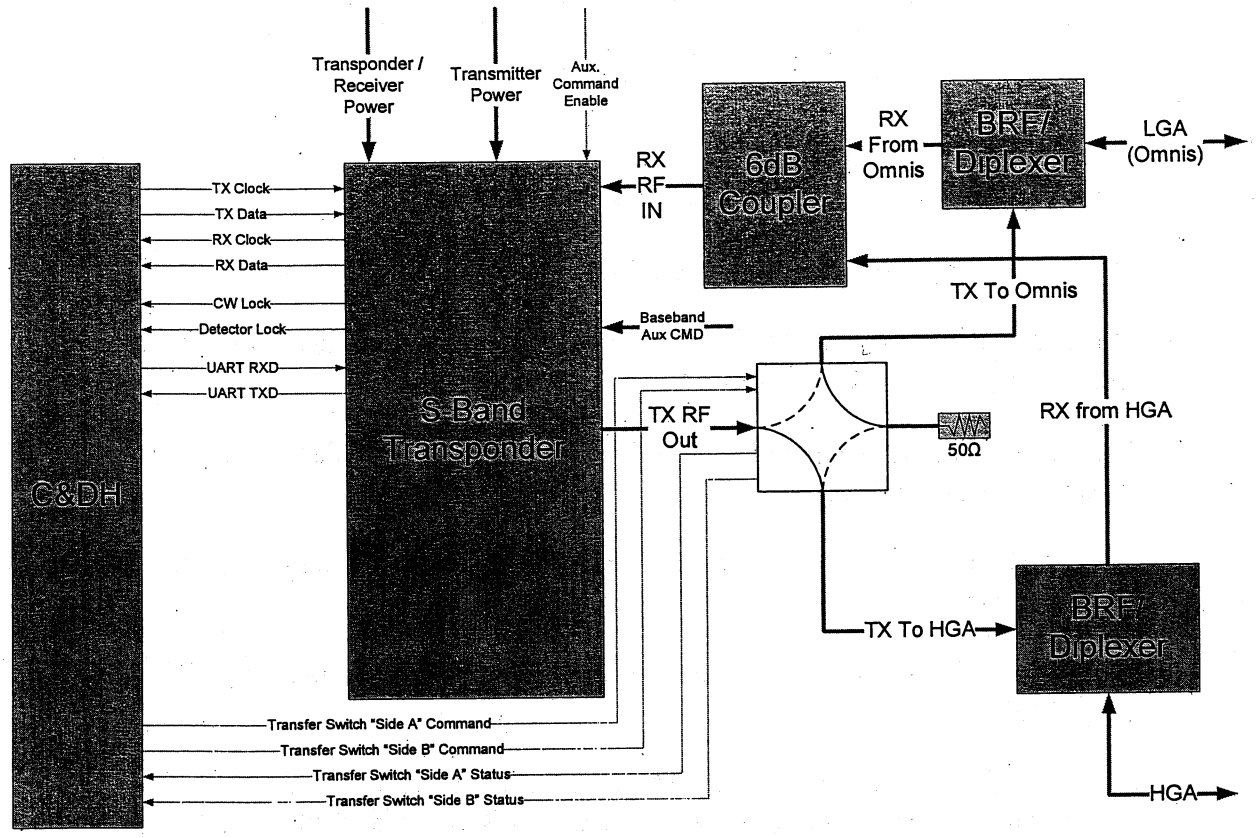


Figure 3-2. TT&C Subsystem Block Diagram

3.2 FUNCTIONAL AND PERFORMANCE REQUIREMENTS

3.2.1 Integrated Subsystem

STPS-1 The TT&C subsystem shall consist of a STDN compatible transponder, two BRF/diplexers, a RF switch, a 6 dB coupler, the cables necessary to connect them, and any necessary RF and signal termination. The Contractor may elect to use individual BRF and diplexer filter assemblies rather than an integrated unit.

STPS-2 The individual components of the TT&C Subsystem shall be integrated as a single functional unit.

STPS-3 The TT&C subsystem shall provide the capability to connect simultaneously to LGA and HGA RF receive paths.

STPS-4 The TT&C subsystem shall provide the capability to select between LGA and HGA RF transmit signal paths.

STPS-5 Subsystem interconnects including power, RF and signal cabling between components shall comply with the Lunar Reconnaissance Orbiter Electrical Systems Specification (431-RQMT-000008).

3.2.1.1 Subsystem Operational Modes

STPS-6 The TT&C subsystem shall accept a S-Band uplink signal.

STPS-7 The TT&C subsystem shall transmit a S-Band downlink signal.

STPS-8 The TT&C subsystem shall receive downlink telemetry from the LRO command and data handling (C&DH) subsystem.

STPS-9 The TT&C subsystem shall modulate the downlink telemetry data on the transmitted downlink signal.

STPS-10 The TT&C subsystem shall demodulate received uplink command from the LRO Ground System.

STPS-11 The TT&C subsystem shall provide the demodulated uplink data to the LRO C&DH subsystem.

STPS-12 The TT&C subsystem shall support radiometric measurement by National Aeronautics and Space Administration (NASA) STDN compatible ranging.

STPS-13 The TT&C subsystem shall support radiometric measurement by NASA Deep Space Network (DSN) compatible ranging.

STPS-14 The TT&C subsystem shall support radiometric measurement by coherent Doppler techniques.

STPS-15 The TT&C subsystem shall support simultaneous uplink command reception, downlink telemetry, and radiometric range and Doppler functions.

3.2.1.2 Subsystem Operating Conditions

STPS-16 The TT&C subsystem shall meet the requirements of this specification while under mechanical stimulus.

STPS-17 The TT&C subsystem shall meet the requirements of this specification when operating in the temperature range from -10 degrees centigrade (°C) to +50°C.

STPS-18 The TT&C subsystem shall not be damaged by temperatures within the range from -20°C to +60°C.

3.2.1.3 Subsystem Passive Losses

STPS-19 The total passive loss in the LGA (omnidirectional antenna system) receive path, measured from the LGA diplexer antenna port to the transponder receiver port, shall not exceed 1.3 dB.

STPS-20 The total passive loss in the LGA (omnidirectional antenna system) transmit path, measured from the transponder transmitter port to the LGA diplexer antenna port, shall not exceed 1.6 dB.

STPS-21 The total passive loss in the HGA receive path, measured from the HGA diplexer antenna port to the transponder receiver port, shall not exceed 8.7 dB.

STPS-22 The total passive loss in the HGA transmit path, measured from the transponder transmitter port to the HGA diplexer antenna port, shall not exceed 1.2 dB.

3.2.2 Transponder

3.2.2.1 Operating Modes

STPS-23 The transponder shall receive a S-Band uplink signal.

STPS-24 The transponder shall transmit a S-Band downlink signal.

STPS-25 The transponder shall support STDN compatible ranging.

STPS-26 The transponder shall support DSN compatible ranging.

STPS-27 The transponder receiver shall always be on.

STPS-28 The transponder transmitter shall be controlled on/off.

3.2.2.1.1 Command Demodulation

STPS-29 The transponder shall demodulate command data from the received uplink signal.

STPS-30 The transponder shall provide the received uplink data to the LRO C&DH subsystem.

STPS-31 The receiver shall demodulate a 4 kilo-bit/second (kbps) command data stream that has been Binary Phase Shift Keyed (BPSK) modulated onto a 16 kiloHertz (kHz) subcarrier.

3.2.2.1.1.1 Uplink Command Demodulation

STPS-32 The transponder shall accept an uplink carrier that is phase modulated with a 16 KHz BPSK modulated subcarrier.

STPS-33 The receiver shall demodulate the command subcarrier from the S-Band uplink signal.

STPS-34 The receiver shall detect the command data from the subcarrier.

STPS-35 The receiver shall provide the received command message bit stream to the C&DH Subsystem.

3.2.2.1.1.2 Auxiliary Command

STPS-36 The transponder shall provide an auxiliary command interface that accepts a baseband modulated 16 KHz subcarrier signal controlled by an Auxiliary Command Enable signal.

STPS-37 In the absence of receiver carrier lock, and upon receipt of the Auxiliary Command Enable signal, the receiver's detector shall demodulate the command data from the baseband modulated subcarrier from the auxiliary command input and provide the command message bit stream to the C&DH Subsystem.

3.2.2.1.2 Downlink Telemetry Modulation

STPS-38 The transponder shall provide two modes to modulate the downlink carrier with the digital telemetry data received from the C&DH Subsystem.

STPS-39 The transponder shall provide a direct carrier downlink modulation mode.

STPS-40 The transponder shall provide a subcarrier downlink modulation mode.

STPS-41 The transponder shall provide the capability to select whether the telemetry data modulates the carrier or the subcarrier, using a Telemetry Subcarrier Enable command.

3.2.2.1.2.1 Direct Carrier Downlink Telemetry Modulation

STPS-42 The transponder, in the absence of the Telemetry Subcarrier Enable, shall directly modulate the downlink S-Band carrier with the telemetry data received from the C&DH.

STPS-43 The transponder shall use BPSK modulation to directly modulate the downlink carrier.

3.2.2.1.2.2 Subcarrier Downlink Telemetry Modulation

STPS-44 When commanded by the Telemetry Subcarrier Enable, the transponder shall modulate telemetry data on an internally generated 1.7 Megahertz (MHz) subcarrier.

STPS-45 The 1.7 MHz data modulated subcarrier shall phase modulate the downlink carrier signal with a modulation index of 1.5 radians peak.

STPS-46 The transponder shall use BPSK modulation to modulate the downlink subcarrier with telemetry data.

3.2.2.1.3 Tracking Operation

STPS-47 The transponder shall generate a downlink carrier signal that is phase and frequency coherent to the received S-Band uplink carrier signal.

STPS-48 The transponder shall demodulate the ranging signal from the uplink carrier and re-modulate the signal on the downlink carrier upon receipt of a suitable command from the spacecraft C&DH Subsystem enabling ranging mode. The turnaround modulation index will be 0.5 radians peak for a single tone.

STPS-49 Remodulation of the received ranging signal shall be controlled by the Ranging Channel Enable command.

3.2.2.1.4 Coherent Operation

STPS-50 The ratio of the transponder generated downlink carrier signal frequency to the frequency of the received uplink carrier frequency shall be 240/221.

STPS-51 Coherent generation of the downlink carrier shall be controlled by the Coherent Downlink Enable command.

STPS-52 The coherent downlink signal shall be generated using a phase locked loop. The Contractor may elect to use a numerically controlled oscillator (NCO) or a voltage controlled crystal oscillator (VCXO) as appropriate to their design.

STPS-53 The transponder shall provide a temperature compensated crystal oscillator (TCXO) to produce an internally generated reference frequency in the absence of an uplink carrier frequency reference or in the absence of the Coherent Downlink Enable command.

STPS-54 The time from the receiver carrier in-lock indication to the switching of transmitter reference frequency from the TCXO to the Phase Locked Loop (PLL) (specified in STPS-52) shall not exceed one second.

3.2.2.1.5 Non-Coherent Operation (One-Way)

STPS-55 In the absence of an S-Band uplink signal or in the absence of the Coherent Downlink Enable and the Ranging Channel Enable commands, the S-Band downlink carrier frequency shall be derived from an internal TCXO.

STPS-56 The time for the transmitter to switch to the TCXO after loss of receiver lock shall be at least two (2) seconds and not greater than four (4) seconds. The carrier lock status telemetry will be used as the loss of lock indicator.

3.2.2.2 Transmitter Characteristics

STPS-57 Unless otherwise stated, the parameters described in this section shall apply when referenced to the antenna port of either diplexer.

STPS-58 The transmitter shall meet the requirements of this section within 10 seconds of prime power application unless otherwise specified.

3.2.2.2.1 Frequency

STPS-59 The transponder shall operate at a downlink frequency of 2271.2 MHz.

STPS-60 The downlink frequency, when operating in the non-coherent mode using the internal TCXO, shall meet requirements STPS-61, STPS-62, STPS-63, and STPS-64 using a 1 second integration time after 1 minute of operation.

STPS-61 The transmitter frequency shall be set at the time of manufacture within ±0.5 parts per million (PPM) of the assigned center frequency at a temperature of 24 ±2 °C.

STPS-62 The transmitter shall not vary more than ±10 PPM from the set value over the temperature range of -10°C to +50°C and more than ±20 PPM from the set value over the temperature range of -20 °C to +60 °C.

STPS-63 At any constant temperature (±0.5 °C) in the range from -10°C to +50°C, the Root Mean Squared (RMS) fractional frequency deviation over a 10 minute period, measured with a 10 second integration time, shall not exceed $2x10^{-9}$.

STPS-64 At any constant temperature (±0.5 °C) in the range from -10°C to +50°C, the frequency shall not vary more than ±3 PPM from the set value over a period of one year.

3.2.2.2.2 RF Output

STPS-65 The transmitter RF power output at the antenna port of either diplexer shall be 5 watts (W) +2/-0 dB.

3.2.2.2.2.1 Output Impedance

STPS-66 The impedance at the transmitter output connector (looking into the output) shall be nominally 50 ohms with a maximum Voltage Standing Wave Ratio (VSWR) of 1.5:1 over the frequency of 2271.2 MHz ±5 MHz.

3.2.2.2.2.2 Output Protection

STPS-66 The transmitter shall be capable of surviving an open or short condition at the RF output port indefinitely without permanent damage or degradation in performance.

3.2.2.2.2.3 Amplitude Modulation

STPS-67 Amplitude modulation of the transmitter output signal shall not exceed 1% with no modulation or 2% at any modulation index up to 2 radians peak by any frequency in the frequency response specified in Section 3.2.2.3.3.

3.2.2.2.2.4 Residual Phase Modulation

STPS-68 With a S-Band input signal level of -90 dBm at the receiver input, the residual phase modulation (noise) or dynamic phase error (DPE) measured at the transmitter output shall be less than 3° RMS. This requirement does not apply during mechanical stimulus (vibration or shock).

STPS-69 There shall be no malfunction of the transmitter during mechanical stimulation.

3.2.2.2.2.5 Internal VCXO Feed-through

STPS-70 The phase modulation contributed by the transmitter PLL shall not exceed 1.5° RMS.

3.2.2.2.2.6 Spurious Outputs

STPS-71 The emissions out of the diplexer antenna port shall not exceed a level of 60 dB below the unmodulated carrier in the span 100 kHz to 18 Gigahertz (GHz), except at f_T ±10 MHz, and the second and third harmonics of the carrier.

STPS-72 Emissions at f_T ±10 MHz and the 2^{nd} and 3^{rd} harmonics shall comply with the National Telecommunication and Information Administration (NTIA) spectral mask for S-Band space-to-Earth transmissions.

STPS-73 A load with a VSWR of not greater than 1.7:1 shall be used to verify that the spurious outputs are below the specified level.

3.2.2.2.2.7 Command Suppression of Downlink Signal

STPS-74 The uplink command modulation for any receiver input signal level (specified in Section 3.2.2.3.2.1) shall not cause suppression of the downlink carrier by more than 0.1 dB when the ranging channel is off.

3.2.2.2.3 Telemetry Channel Characteristics

STPS-75 The data from the telemetry channel shall modulate either the S-Band carrier or the downlink subcarrier, depending on whether the Telemetry Subcarrier Enable is ENABLED.

STPS-76 The telemetry channel bandwidth shall be from 100 Hz to 5 MHz offset from the carrier frequency.

STPS-77 A positive going voltage transition at the telemetry input shall cause the phase of the RF carrier to advance (become more positive).

3.2.2.2.4 Subcarrier Data Modulation

STPS-78 The frequency of the telemetry subcarrier shall be 1.7 MHz ±0.005%.

STPS-79 Subcarrier telemetry data rate shall be between 286.25 symbols/sec and 586.24 kilo-symbols/sec.

3.2.2.2.4.1 Carrier Modulation Index

STPS-80 The modulation index shall be set at the time of manufacture to within ±5% of the specified value.

3.2.2.2.4.2 Carrier Modulation Index Stability

STPS-81 The modulation index shall remain within ±10% of the specified value over the full qualification temperature range as specified in Section 3.7.1 of this specification.

STPS-82 The modulation index shall remain within ±5% of the specified value over the data rates specified in Section 3.2.2.2.4.

3.2.2.2.5 Direct Carrier Data Modulation

STPS-83 S-Band carrier telemetry rates shall be between 286.2 symbols/sec and 2.50297 mega-symbols/sec.

STPS-84 The carrier suppression due to direct data modulation shall be at least 20 dB for all downlink data rates.

3.2.2.3 Receiver Characteristics

STPS-85 The receiver shall meet all requirements within 10 seconds of prime power application. Unless otherwise stated, the parameters described in this section are referenced to antenna port of either diplexer.

STPS-86 The receiver shall be capable of meeting the requirements of this section when provided an uplink composite input signal consisting of a command subcarrier and/or ranging signals.

STPS-87 Unless otherwise stated, the receiver shall meet all the requirements of this section with the transmitter on and operating.

STPS-88 The receive noise figure of the TT&C subsystem, as measured at the LGA diplexer antenna port shall be less than 5 dB.

STPS-468 The receive noise figure of the TT&C subsystem, as measured at the HGA diplexer antenna port shall be less than 11.5 db.

3.2.2.3.1 Frequency

STPS-89 The nominal received uplink carrier frequency shall be 2091.3967 MHz.

STPS-90 The receiver frequency (f_R) stability shall meet the following requirements with a 1 second integration time after 10 minutes of operation.

STPS-91 The receiver frequency shall be set, at the time of receiver alignment during manufacture, to the assigned design center frequency within ±2 PPM at a temperature of 24 ±2°C.

STPS-92 The receiver frequency shall not vary more than ±20 PPM from the set value over the temperature range of -20°C to +60°C.

STPS-93 The receiver frequency shall not vary more than ±1.5 PPM from the set value over a period of 15 hours at any constant temperature (±0.5°C) in the range from -10°C to +50°C.

STPS-94 The receiver frequency shall not vary more than ±3 PPM from the set value over a period of 1 year at any constant temperature (±0.5°C) in the range from -10°C to +50°C.

3.2.2.3.2 Command Channel Characteristics

STPS-95 The command information shall be transmitted on the uplink carrier in the form of a BPSK-modulated 16 kHz sinewave subcarrier.

STPS-96 The receiver shall demodulate the uplink carrier to produce the command subcarrier signal.

STPS-97 The detector shall detect the command data and provide data, bit timing, and lock indication signals to the C&DH Subsystem.

STPS-98 The command detector shall be capable of meeting the requirements of this section when provided an uplink composite input signal consisting of a command subcarrier and/or ranging signals. The composite modulation index due to the command and ranging signals will be less than 2.5 radians peak.

STPS-99 Unless otherwise stated, the command detector shall meet all the requirements of this section with the transmitter on and operating.

STPS-100 The command channel pre-detection bandwidth shall be less than 45 kHz.

3.2.2.3.2.1 Command Parameters

STPS-101 Command channel parameters shall be as shown in Table 3-1.

Table 3-1. Command Channel Parameters

Parameter	Value
Data Rate	4000 symbols per second
Data Format	Non-Return-to-Zero, Logic Level Coding (NRZ-L)
Subcarrier Type	16 kHz sinewave
Subcarrier Modulation	BPSK Modulation
Carrier Modulation	Linear Phase Modulation
Carrier Modulation Index	1.5 radians for command only (no ranging) 1.8 radians max for command and ranging (0.4 radians CMD, 0.7 radians ranging for a single tone. Two tones will contribute 0.7 radians each)
Command Threshold (total RF power into the receiver for an uplink bit error rate [BER] of 10^{-5})	-118 dBm (command only, no ranging)

3.2.2.3.3 Signal Level Range at Diplexer Antenna Port

STPS-102 The receiver shall operate in accordance with this specification over an uplink signal level range from the carrier tracking threshold (see Table 3-9) to -50 dBm measured at the diplexer antenna port.

STPS-103 The receiver shall not be damaged by uplink signal levels up to +10 dBm as measured at the diplexer antenna port.

3.2.2.3.4 Input Impedance

STPS-104 The characteristic impedance of the receiver input terminal shall be a nominal 50 ohms with a VSWR of not greater than 1.5:1 over a frequency range of 2091.3967 MHz ±2.5 MHz.

STPS-105 With the diplexer connected to the transponder, the characteristic impedance at the diplexer antenna port shall be a nominal 50 ohms with a VSWR of not greater than 1.7:1 over a frequency range of 2091.3967 MHz ±2.5 MHz.

3.2.2.3.5 Phase Lock Loop Performance

STPS-106 The phase lock loop design shall use a second order loop filter having characteristics shown in Table 3-2.

Table 3-2. Characteristics of Second Order Phase Lock Loop Filter

Parameter	Value
Noise Bandwidth (2βLo)	750 Hz ±10%
Pre-Detection Bandwidth	1 MHz
Filter Damping Factor	0.707 (S/N=1 in 2βLo)

3.2.2.3.6 Signal Acquisition

STPS-107 Acquisition shall occur when an unmodulated uplink signal is swept through the specified center frequency of the receiver. Signal level and sweep requirements are as given in Table 3-3. Signal levels are measured at the diplexer antenna port.

Table 3-3. Signal Acquisition Performance Characteristics

Parameter	Value
Signal Level Range	-124 dBm to -50 dBm
Signal Sweep Range	F_R ±140 kHz
Signal Sweep Rate	1 kHz/sec to 35 kHz/sec
Acquisition Threshold	-124 dBm

STPS-108 The receiver shall reacquire the uplink without the aid of ground sweep for signal dropout durations up to 50 msec. This applies for tracking a STDN signal with Doppler rates up to 6 kHz/sec.

STPS-109 The receiver shall detect a CW signal swept through the receiver center frequency with a probability greater than 99%.

3.2.2.3.7 Signal Tracking

STPS-110 Received command modulated uplink signal tracking performance of the receiver shall be as specified in Table 3-4 at the antenna port of the diplexer.

Table 3-4. Receiver Tracking Performance

Parameter	Value
Tracking Threshold	-124 dBm (sweep mode) -127 dBm (at the receiver best lock frequency)
Tracking Range	$f_R \pm 140$ kHz (with a -110 dBm input level)
Tracking Rate	≥25 kHz/sec (for uplink signal levels ≥ -110 dBm) ≥35 kHz/sec (for uplink signal levels ≥ -90 dBm)
Static Tracking Error	≤1° per 30 kHz (at signal levels greater than -110 dBm)

STPS-111 The receiver shall maintain lock in the absence of frequency dynamics for 1 minute or more with a probability greater than 95%.

3.2.2.3.8 Carrier Automatic Gain Control Loop

STPS-112 The receiver shall use a coherent Automatic Gain Control (AGC) loop.

STPS-113 The AGC loop noise bandwidth (two sided) shall be between 15 Hz and 45 Hz.

STPS-1114 The variation in AGC voltage versus uplink carrier power level shall be characterized from -127 dBm to -50 dBm.

STPS-115 Calibration curves or measured data shall be provided for -20°C, -10°C, 25°C, 40°C, and 55°C.

3.2.2.3.9 Spurious Signal Rejection

STPS-116 The receiver shall not be degraded below the specified performance when presented with the following signals in Table 3-5 at its input. As this is a requirement on the subsystem, and not the receiver alone, contributions from filters external to the transponder may be used to meet this requirement.

Table 3-5. Receiver Spurious Signal Rejection

Frequency	Signal Level Above Receiver Threshold
Primary Image Frequency	60 dB
$f_o \pm$ ½ 1st IF Frequency $f_o \pm$ ¼ 1st IF Frequency $f_o \pm$ ½ 2nd IF Frequency $f_o \pm$ ¼ 2nd IF Frequency	50 dB
All other frequencies ± 5 MHz outside design center frequency	80 dB

Note: f_o is the receiver best lock frequency

3.2.2.3.10 Transmitter Degradation of Command Threshold

STPS-117 The command threshold of the detector shall not be degraded by more than 0.5 dB when the transmitter is turned on and operating.

3.2.2.3.11 Acquisition and Tracking Performance

STPS-118 The length of the command acquisition sequence shall be 132 symbols for a probability of acquisition of 0.99. The command acquisition sequence is defined as a data sequence of alternating ones and zeros at 4000 symbols per second (BPSK modulating a 16 kHz sinewave subcarrier).

STPS-119 The detector shall acquire and track the subcarrier and data transitions of the command signal when the frequency is 16 kHz ±1.6 Hz with a maximum rate of change of ±0.05 Hz/sec.

STPS-120 The probability that the detector fails to indicate the in-lock condition in response to receipt of the command acquisition sequence shall be $\leq 1x10^{-4}$ at and above the command threshold defined in Table 3-10.

STPS-121 The probability that the detector will indicate the in-lock condition in the presence of noise alone shall be $\leq 1x10^{-4}$ in any interval containing two lock decisions.

STPS-122 The probability that the detector will indicate the out-of-lock condition within 27 symbol times of removing the command signal at the detector input shall be $\geq$ 0.98.

STPS-123 At the command threshold defined in Table 3-10, the probability that the detector will indicate the out-of-lock condition shall be $\leq 2.5x10^{-9}$ in any interval containing two lock decisions.

3.2.2.4 Coherent Ranging

STPS-124 The transponder shall support coherent (two-way) radiometric range and range-rate measurement.

STPS-125 Modulation of the downlink carrier by the received ranging channel shall be enabled when the Ranging Channel Enable command is ENABLED.

3.2.2.4.1 Uplink Ranging Signal

STPS-126 The transponder shall be able to receive and support the following USB tone ranging signals: 20 kHz, 100 kHz, or 500 kHz major range tones and 100 kHz, 20 kHz, 4 kHz, 800 Hz, 160 Hz, 40 Hz, and 10 Hz minor ambiguity resolution tones and Ambiguity Resolution Code (ARC), as generated by the ground station, to establish initial range. (Note that the minor tones below 4 kHz and the Ambiguity Resolution Code (ARC) are sequentially bi-phase modulated on the 4 KHz tone with the 800 Hz tone transmitted as an upper sideband at 4.8 kHz.

STPS-127 The transponder shall be able to receive and support the DSN sequential ranging signals as defined in DSN 810-5.

STPS-128 The uplink ranging modulation index shall be between 0.35 to 0.7 radians peak (single tone) and between 0.7 to 1.4 radians peak for two tones.

3.2.2.4.2 Downlink Ranging Modulation Index

STPS-129 The transponder shall demodulate the ranging tone(s) from the uplink carrier and remodulate it(them) on the downlink carrier.

STPS-130 The downlink ranging modulation index shall be set with a channel Signal-to-Noise Ratio (SNR) of 20 dB or greater in the post detection bandwidth (Section 3.2.2.5.4).

STPS-131 The ranging channel downlink modulation index shall be adjustable during manufacture to any value in the range from 0.35 to 1.5 radians peak (single tone sinewave).

STPS-132 The user shall specify the downlink modulation index at the time of transponder contract award.

STPS-133 The modulation index shall be set at the time of manufacture to within ±5% of the specified value.

STPS-134 The total RMS signal plus noise downlink ranging modulation index shall be within ±10% of the set value over the temperature range (-10 °C to +55 °C) and within ±13% over the temperature range (-20 °C to +65 °C).

3.2.2.4.3 Ranging Channel Input / Output Polarity

STPS-135 A positive ranging modulation phase deviation on the uplink carrier shall cause a positive phase deviation on the downlink carrier.

3.2.2.4.4 Ranging Channel Bandwidth

STPS-136 The turnaround ranging post-detection upper 3dB bandwidth shall be 800 kHz (=1.6 times the highest frequency sinewave of 500 kHz).

3.2.2.4.5 Ranging Channel Frequency Response and Non-Linearity

STPS-137 The ranging channel baseband frequency response shall be uniform within ±1.0 dB within the frequency range of 3 kHz to 500 kHz.

STPS-138 The ranging channel shall be designed not to deviate more than ±6° from a linear phase-frequency relationship within the same frequency range.

STPS-139 The phase-amplitude conditions shall be met with received RF signal levels between -120 dBm and -50 dBm.

3.2.2.4.6 Ranging Channel Absolute Delay

STPS-140 The turnaround ranging channel absolute delay shall not exceed 2.5 microseconds (μs) as measured at the antenna port of either diplexer.

STPS-141 The turn-around ranging channel time delay variation for the full range of Doppler input level, temperature, voltage and life shall be less than ±40 nanoseconds (ns).

STPS-142 Data shall be supplied correlating the input voltage, temperature, and predicted Doppler such that it shall be possible to predict the delay to within ±10 ns.

3.2.2.5 Control, Monitoring and C&DH Interface

STPS-143 The transponder shall provide status signals indicating its operating mode and operating parameters to the C&DH Subsystem.

STPS-144 The transponder shall accept control signals from the C&DH Subsystem to configure the transponder and set its operating modes.

STPS-145 The presence or absence of any combination of the input signals applied in any sequence shall not damage the transponder, reduce its life expectancy, or cause any malfunction, either when the unit is powered or when it is not.

STPS-146 The transponder shall provide a register based, serial Universal Asynchronous Receiver/Transmitter (UART) interface to enable control and monitoring by the C&DH. The behavior of this interface is specified in Section 3.2.2.5.3.

STPS-147 The transponder shall provide discrete digital signals to enable direct control and monitoring of status by the C&DH. The provided signals will include a carrier lock indicator, a command detector lock indicator, and a Baseband Auxiliary Command enable. The behavior of these signals is specified in Sections 3.2.2.5.1 and 3.2.2.5.4.

STPS-148 The transponder shall provide clock and data signals to provide received command data to the C&DH.

STPS-149 The transponder shall accept clock and data signals to receive downlink telemetry symbols from the C&DH.

3.2.2.5.1 C&DH Command / Telemetry Interface

STPS-150 The transponder C&DH command/telemetry interface shall be as described in the following paragraphs. Command and telemetry data interface signals are detailed in Table 3-6. The timing relationship between these signals, and between the transponder and the C&DH S-Band Communication Card (S-COMM) is illustrated in Figure 3-3.

Table 3-6. Command and Telemetry Interface Signal Definition

Description	Signal Type
Received Command Data	Digital Differential Pair, RS-422
Received Command Clock	Digital Differential Pair, RS-422
Detector Lock Indicator	Digital Differential Pair, RS-422
Telemetry Data Symbols	Digital Differential Pair, RS-422
Telemetry Symbol Timing Clock	Digital Differential Pair, RS-422

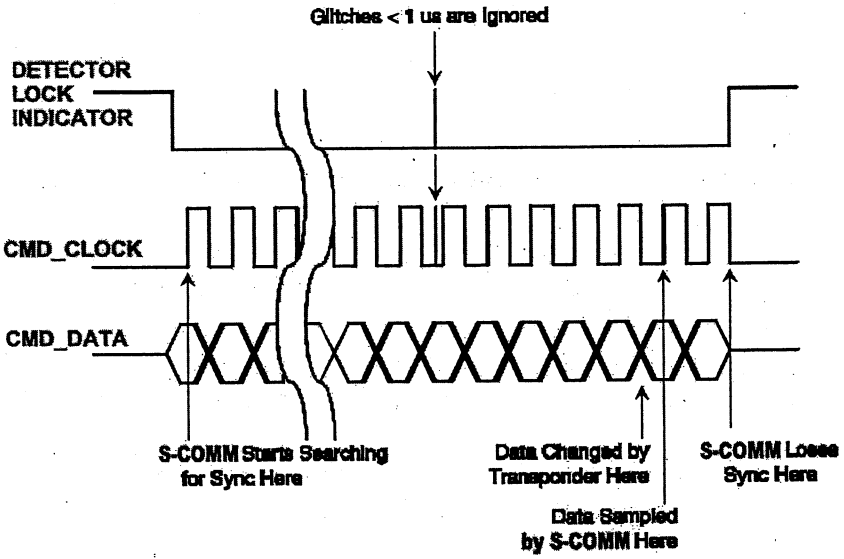


Figure 3-3. Received Data to C&DH Signal Timing Diagram

STPS-151 The command and telemetry data interface signals shall comply with the RS-422 electrical specification. Figure 3-4 depicts the RS-422 interface between the C&DH and the Transponder.

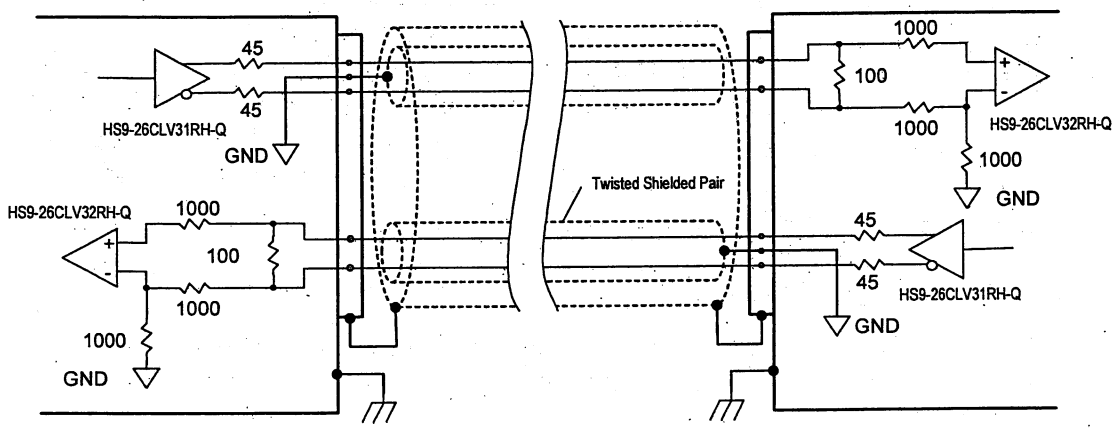


Figure 3-4. RS-422 Electrical Specification

STPS-152 The twisted pair shield of all RS-422 signals shall connect to driver-side ground.

STPS-153 Overall RS-422 cable shields shall connect to chassis ground at both ends.

STPS-154 RS-422 receivers shall use shunt termination with biasing for fail-safe operation.

STPS-155 The impedance of cables used in RS-422 connections shall be 100 ohms.

STPS-156 The output impedance of RS-422 signal drivers shall be 10 ohms.

STPS-157 The transponder shall not be damaged by an open or short condition at any telemetry input or command output signal.

3.2.2.5.2 C&DH Telemetry Data Interface

STPS-158 The transponder shall accept downlink telemetry from the C&DH Subsystem.

STPS-159 The transponder shall provide a downlink telemetry data signal input to receive outbound symbols in NRZ-L format from the C&DH Subsystem.

STPS-160 The transponder shall provide a downlink telemetry clock signal input to receive outbound symbol timing in NRZ-L format from the C&DH Subsystem.

STPS-161 The maximum telemetry symbol transfer rate from the C&DH Subsystem to the transponder shall be 2.50297 mega-symbols/second.

STPS-162 The minimum telemetry symbol transfer rate from the C&DH Subsystem to the transponder shall be 286.25 symbols/second.

STPS-163 The telemetry channel waveform time asymmetry shall not exceed 1%.

STPS-164 The transponder telemetry data interface shall be tested at the following data rates: 286.25 symbols/second, 4.58 kilo-symbols/second, 36.64 kilo-symbols/second, 73.28 kilo-symbols/second, 146.56 kilo-symbols/second, 293.12 kilo-symbols/second, 586.24 kilo-symbols/second, 2502.97 kilo-symbols/second. Note that these rates represent the LRO data rates (125 bps, 2 kbps, 16 kbps, 32 kbps, 64 kbps, 128 kbps, 256 kbps, 1.093 megabits per second [Mbps]) after Forward Error Correction (FEC) coding.

3.2.2.5.3 C&DH Command Data Interface

STPS-165 The transponder shall provide a command data output signal to the C&DH Subsystem to provide received command data symbols to the C&DH.

STPS-166 The transponder shall provide a command clock output signal to the C&DH Subsystem to provide received command data symbol timing to the C&DH.

STPS-167 The transponder shall provide a discrete detector lock indicator signal to the C&DH Subsystem.

STPS-168 Deleted

3.2.2.5.3.1 Command Data

STPS-169 The command data shall be demodulated from the 16 kHz subcarrier in the uplink signal and sent to the C&DH Subsystem.

STPS-170 The command data shall be clocked on the rising edge of the command clock.

STPS-171 The command data shall be provided to the C&DH in NRZ-L format.

STPS-172 The transponder shall pass command data from the command detector to the C&DH when the detector lock indicator is active.

STPS-173 The transponder received command clock and data signals shall output a logic "0" when the command detector is not in lock.

STPS-174 The detector shall maintain lock for data streams containing up to 64 continuous 1's or 0's.

3.2.2.5.3.2 Command Clock

STPS-175 The command clock shall be a squarewave at the data rate.

STPS-176 The clock shall only be provided to the C&DH when the detector lock indicator is active.

3.2.2.5.4 Auxiliary (Hardline) Command Interface

STPS-177 The transponder shall accept an externally generated composite baseband signal as an alternate method of sending commands when RF communication with the transponder is impossible or undesirable.

STPS-178 The transponder shall utilize a separate external signal to enable commanding via the auxiliary command interface. This signal is the Auxiliary Command Enable.

STPS-179 Deleted

STPS-180 The auxiliary command input and Auxiliary Command Enable lines shall be designed with transient protection in the event of a nearby lightning strike during expendable launch vehicle (ELV) pad operations as lightning can induce transient energy into the spacecraft wiring, especially the spacecraft umbilical cable(s).

Of concern is circuit damage due to induced lightning. RTCA-DO160E, Section 22 specifies indirect lightning waveforms, levels and test method including setup and calibration procedures as specified below. Note verification by analysis only is acceptable, there is no requiring active transient suppression testing.

At the launch complex, assume a Level 3 environment (intended for equipment and interconnecting wiring in a moderately exposed electromagnetic environment).

Level	Waveform 3 Voc/Isc *	Waveform 4 Voc/Isc ***
3	600/24	300/60

* See Figure 22-4 for Waveform 3, which is a damped sine, 1 MHz of RTCA-DO160.

** Waveform 4 is a unipolar pulse with T1 = 6.4 microseconds and T2 = 69 microseconds as shown in Figure 22-5.

Note: Voc represents the open circuit test generator voltage in Volts and Isc represents the generator short circuit current in Amperes.

3.2.2.5.4.1 Auxiliary Command Enable

STPS-181 Auxiliary commanding shall only be enabled when the receiver is not locked to an RF uplink signal. The transponder will "lock out" the Auxiliary Command Enable signal when the receiver locks to an RF uplink signal.

STPS-182 When the receiver is locked to an RF uplink signal, the transponder shall ignore the auxiliary command input regardless of the status of the enable signal. The requirements for the auxiliary command signal switching are given in Table 3-7.

Table 3-7. Auxiliary Command Behavior

Receiver Locked to RF Uplink	Auxiliary Command Enable	Command Path	Receiver In-Lock Telemetry Status	Detector In-Lock Telemetry Status
Yes	Disabled	RF	In-Lock	In or Out
Yes	Enabled	RF	In-Lock	In or Out
No	Disabled	N/A	Out-of-Lock	Out-of-Lock
No	Enabled	Hardline	Out-of-Lock	In-Lock

STPS-183 The external Auxiliary Command Enable shall be activated by an external switch closure. Two lines will be provided by the transponder, and an electrical short between them will enable the Auxiliary Command Enable input.

3.2.2.5.4.2 Auxiliary Command Signal Characteristics

STPS-184 The external baseband Auxiliary Command signal shall be a differential signal.

STPS-185 The Auxiliary Command signal input shall be terminated in 600 ±30 ohms inside the transponder.

STPS-186 The impedance of either line of the Auxiliary Command signal to chassis ground shall be greater than 4.7 k-ohms.

STPS-187 The auxiliary command signal shall consist of a 16 kHz sinewave, BPSK modulated with NRZ-L binary command data, at a bit rate of 4000 symbols per second.

STPS-188 The auxiliary command signal level at the input to the transponder shall be 4.5 ±1.0 Volts peak-to-peak (p-p), line-to-line.

STPS-189 The receiver shall accurately detect and demodulate the auxiliary command signal when the signal appears in the presence of common mode noise of up to 9 volts peak at frequencies up to 100 kHz.

STPS-190 The transponder shall operate within the requirements of this document when as much as fifteen hundred (1500) feet of un-terminated cabling is connected to the auxiliary command signal interface at the input of the transponder.

3.2.2.5.5 Transponder Control & C&DH Commanding

STPS-191 The transponder shall provide control of the following functions through the transponder serial UART interface: Transmitter ON/OFF, Telemetry Subcarrier Enable, Ranging Channel Enable, Coherent Downlink Enable, and Auxiliary Oscillator Enable.

STPS-192 Deleted

STPS-193 Deleted

3.2.2.5.5.1 Transmitter ON/OFF Command

STPS-194 If the Transmitter ON/OFF Command is in the ON state, the RF transmitter section of the transponder shall be active and producing modulated RF at the output port.

STPS-195 If the Transmitter ON/OFF Command is in the OFF state, the RF transmitter section of the transponder shall be inactive, and no RF will be present at the output port.

3.2.2.5.5.2 Telemetry Subcarrier Enable Command

STPS-196 When the Telemetry Subcarrier Enable is in the ENABLED state, the telemetry data shall BPSK modulate the internally generated subcarrier.

STPS-197 If the Telemetry Subcarrier Enable is in the DISABLED state, the telemetry data shall modulate the S-Band carrier directly.

3.2.2.5.5.3 Ranging Channel Enable

STPS-198 If the Ranging Channel Enable is in the ENABLED state, the transponder shall remodulate the received ranging signal (STDN ranging tones) on the downlink carrier.

STPS-199 If the Ranging Channel Enable is in the DISABLED state, the transponder shall not remodulate ranging tones on the downlink carrier.

3.2.2.5.5.4 Coherent Downlink Enable

STPS-200 If the Coherent Downlink Enable is in the ENABLED state, the transponder shall generate a downlink carrier that is phase and frequency coherent with the received uplink carrier.

STPS-201 If the Coherent Downlink Enable is in the DISABLED state, the transponder shall generate the downlink carrier from the internal TXCO reference.

3.2.2.5.5.5 Deleted

STPS-202 Deleted

STPS-203 Deleted

3.2.2.5.5.6 Deleted

STPS-204 Deleted

STPS-205 Deleted

STPS-206 Deleted

STPS-207 Deleted

STPS-208 Deleted

STPS-209 Deleted

3.2.2.5.5.7 Auxiliary Command Enable Discrete Signal

STPS-210 Deleted

STPS-211 The transponder shall interpret an external Auxiliary Command Enable signal as evidence that the Auxiliary Command function is being exercised, and that the receiver should process baseband command streams from the Auxiliary Command port in the absence of carrier lock.

STPS-212 Deleted

3.2.2.5.6 Transponder Status and C&DH Monitoring

STPS-213 The transponder shall provide monitoring of the following analog status and internal telemetry points through the transponder serial UART interface: Receiver Signal Level (AGC voltage), PLL Frequency Offset, Transmitter Output Power, Regulated Receiver Section voltage level, Regulated Transmitter Section voltage level, Transponder Power Supply temperature, Transmitter Power Amplifier temperature.

STPS-214 The transponder shall provide monitoring of the following discrete (Boolean) status and internal telemetry points through the transponder serial UART interface: Receiver Carrier Lock, Receiver Detector Lock, Transmitter ON/OFF, Auxiliary Oscillator ON/OFF, Subcarrier Oscillator Enable ON/OFF, Auxiliary Command Enable ON/OFF, Ranging Channel ON/OFF, Coherent Downlink Enable ON/OFF.

3.2.2.5.7 Transponder Serial UART Control Port Interface

STPS-215 Control and monitoring of the transponder by the C&DH shall be provided through a UART serial port interface.

STPS-216 Serial UART Control Port interface signals shall comply with the RS-422 electrical standard.

STPS-217 The Serial UART Control Port interface data rate shall be 1200 bits per second (bps).

STPS-218 Control of the transponder by the C&DH through the Serial UART Control Port shall be by transmitting an entire Control Frame from the C&DH to the transponder.

STPS-219 The transponder shall accept and process Control Frames at a rate not less than 1 Hz.

STPS-220 Each Control Frame may alter any or all of the states in the transponder, allowing for multiple commands to be sent simultaneously.

STPS-221 The transponder shall update and transmit an entire Monitor Frame to the C&DH at a rate of 10 frames per second.

3.2.2.5.7.1 Serial UART Control Port Framing

STPS-222 Each control/monitor character in the UART interface shall be 10 bits long.

STPS-223 Each 10 bit control/monitor character structure in the serial UART interface shall consist of 1 start bit, 8 data bits, no parity bit and 1 stop bit.

STPS-224 Control framing for the UART interface shall be as shown in Table 3-8.

Table 3-8. UART Control Frame Structure

Character Address	Command/Telemetry Definition	Length
Characters 0,1	Start Frame	16 bits
Characters 2,3	Transponder Command Bits (Digital)	16 bits

STPS-225 Transponder monitor framing for the UART interface shall be as shown in Table 3-9. (Note: The Monitor Frame structure may be changed to accommodate additional bits of resolution for sampled analog signals with approval of the LRO Communication System Lead)

Table 3-9. Transponder UART Monitor Frame Structure

Character Address	Command/Telemetry Definition	Length
Characters 0,1	Start Frame	16 bits
Characters 2,3	Received Signal Level (AGC)	16 bits
Characters 4,5	VCXO Frequency Offset	16 bits
Characters 6,7	Transmitted Output Power Level	16 bits
Characters 8,9	Regulated Receiver Supply Voltage Level	16 bits
Characters 10,11	Regulated Transmitter Supply Voltage Level	16 bits
Characters 12,13	Transponder Receiver Temperature	16 bits

Character Address	Command/Telemetry Definition	Length
Characters 14,15	Transponder Transmitter Temperature	16 bits
Characters 16,17	Transponder Current State Indicators (Boolean bit-masked character)	16 bits

3.2.2.5.7.2 Transponder Status Monitor Framing

STPS-226 Analog (non-Boolean) signals shall be sampled internally by the transponder at 16 bit resolution and provided to the C&DH Subsystem as quantized data. Table 3-6 lists the transponder status telemetry signals available to the C&DH Subsystem.

STPS-227 Digital (Boolean) signals shall be provided as digital bits where a (1) represents an ON or ENABLED state, and a (0) represents an OFF or DISABLED state.

STPS-228 Digital telemetry signals shall be provided to the C&DH as framed bits in the 8th character of the Monitor Frame Structure as shown in Table 3-10.

Table 3-10. Monitor Frame Telemetry Point Definition

Telemetry Signal	Parameter Range / Description	Signal Representation
Receiver Signal Level (AGC)	-127 dBm to -50 dBm	16-bit Quantized Analog See Section 3.2.2.2.7.4
VCXO Frequency Offset	F_R ±150 kHz	16-bit Quantized Analog
Transmitter Output Power	+35 dBm to P_{MAX} dBm P_{MAX} is the maximum output power of the transmitter	16-bit Quantized Analog
Regulated Receiver Section Voltage Level	Voltage ±5%	16-bit Quantized Analog
Regulated Transmitter Section Voltage Level	Voltage ±5%	16-bit Quantized Analog
Transponder Power Supply Temperature	-20 °C to the maximum predicted temperature + 5°C	16-bit Quantized Analog
Transmitter Power Amplifier Temperature	-20 °C to the maximum predicted temperature + 5°C	16-bit Quantized Analog

Telemetry Signal	Parameter Range / Description	Signal Representation
Boolean State Indicators	(representing current state)	(1) Digital, (0) Digital
Receiver Carrier Lock	In-Lock = 1, Out-of-Lock = 0	Bit 0
Detector Lock	In-Lock = 1, Out-of-Lock = 0	Bit 1
Transmitter ON/OFF	ON = 1, OFF = 0	Bit 2
Auxiliary Oscillator ON/OFF	ON = 1, OFF = 0	Bit 3
Subcarrier Oscillator ON/OFF	ON = 1, OFF = 0	Bit 4
Auxiliary Command Enable	Enable = 1, Disable = 0	Bit 5
Ranging Channel ON/OFF	ON = 1, OFF = 0	Bit 6
Coherent Downlink ON/OFF	ON = 1, OFF = 0	Bit 7
RESERVED	N/A	Bits 8-15

3.2.2.5.8 Externally Read Temperature Monitors

STPS-229 Thermistors shall be placed in the transponder in a location indicative of the maximum thermal stresses on the transponder. Such locations may include the RF output power amplifier, thermally sensitive components such as oscillators, and power electronics including regulators, voltage converters and other components of the transponder power supply. Final selection of internal thermistor locations is left to the vendor, but must be coordinated with the LRO Thermal Lead.

STPS-230 The transponder shall use 2.252 ohms S311P18-02-A-7R6 or S311P18-0257R6 thermistors and associated bias circuitry to monitor temperature as specified by the LRO Thermal Lead.

STPS-231 Location of all thermistors in the transponder shall be indicated in the Lunar Reconnaissance Orbiter S-Band Transponder Electrical Interface Control Document (431-ICD-000374) and the Lunar Reconnaissance Orbiter S-Band Transponder Mechanical Interface Control Document (431-ICD-000375).

3.2.2.5.9 Internally Read Temperature Monitors

STPS-232 The transponder shall provide independent temperature monitoring through the C&DH UART control port of the transmitter and the receiver sections. The two measurements will be known as the Transmitter Temperature and the Receiver Temperature.

STPS-233 Internal analog thermistor measurements shall be digitized and made available to the C&DH through the serial UART control port interface.

3.2.2.6 Corona and Multipaction

STPS-234 No evidence of corona or multipaction shall exist at any temperature within the specified operating range when the transponder is undergoing a pressure change

from sea level to 10^{-5} torr or when the transponder is operated at critical pressure or in a hard vacuum.

STPS-235 This requirement (STPS-234) shall be verified by test, with the transmit and receive terminals terminated by matched loads.

3.2.3 Diplexer

3.2.3.1 Operating Modes

STPS-236 The Diplexer shall connect the transponder receiver and transmitter ports to the spacecraft antenna.

3.2.3.2 Diplexer RF Characteristics

3.2.3.2.1 Center Frequency Tunable Ranges

STPS-237 The diplexer receiver channel shall be tuned to the transponder receive frequency.

STPS-238 The diplexer transmitter channel shall be tuned to the transponder transmit frequency.

3.2.3.2.2 Impedance

STPS-239 The RF impedance of all diplexer input and output ports shall have a characteristic impedance of 50 ohms with a maximum VSWR of 1.2:1 over the pass band of ±2.5 MHz about the center frequencies.

3.2.3.2.3 Voltage Standing Wave Ratio

STPS-240 The VSWR of the receive port shall be 1.35:1 maximum over the receive bandwidth with the transmit port terminated in 1.2:1 or better 50 ohms load.

STPS-241 The VSWR of the transmit port shall be 1.35:1 maximum over the transmit bandwidth with the receive port terminated in 1.2:1 or better 50 ohms load.

3.2.3.2.4 Insertion loss and Isolation

STPS-242 The insertion loss and isolation specification for all signal paths in both diplexers shall be as shown in Table 3-11.

STPS-243 The Contractor shall determine appropriate insertion loss and isolation beyond that shown in Table 3-11 to insure no degradation in performance due to transponder self interference.

Table 3-11. Diplexer Insertion Loss & Isolation

Frequency	Between Antenna & Receiver Port	Between Transmit & Antenna Port	Between Transmit & Receiver Port
$F_R \pm 5$ MHz	≤ 0.5 dB	≥ 40 dB	≥ 70 dB
10 MHz to F_R-174 MHz	≥ 40 dB	≥ 40 dB	≥ 40 dB
F_R-174 MHz to F_T+174 MHz	≥ 40 dB	--	--
$F_T \pm 5$ MHz	≥ 60 dB	≤ 0.4 dB	≥ 60 dB
F_T + 174 MHz to 8 GHz	≥ 40 dB	≥ 40 dB	≥ 40 dB

Note: Unused port terminated into a 1:2:1, 50 ohms load. Fr = 2091.4 MHz, Ft = 2271.2 MHz.

3.2.3.2.5 RF Leakage

STPS-244 RF leakage isolation from each diplexer port shall be ≥90 dB when the transmit port is terminated with a 50 ohm load.

3.2.3.2.6 Output Protection

STPS-245 The diplexer shall be capable of surviving an open or short condition at the RF output port indefinitely without permanent damage or degradation in performance.

3.2.3.3 Power Handling

STPS-246 Each diplexer shall be capable of handling the simultaneous transmission of four (4) times the maximum transmitter output RF power through the transmit channel and the reception of RF signals up to +10 dBm through the receive channel, at the specified frequencies, without degradation of performance.

3.2.3.4 Corona and Multipaction

STPS-247 With 4 times the maximum transmitter RF output power (i.e., 24W if the maximum transmitter RF output is 6W) applied to the diplexer's transmit port at the transmit frequency, no evidence of corona or multipaction shall exist at any temperature within the specified operating range when the diplexer is undergoing a pressure change from sea level to 10^{-5} torr or when the diplexer is operated at critical pressure or in a hard vacuum.

STPS-247 This requirement (STPS-247) shall be verified by test, with the antenna and receive terminals terminated by matched loads.

3.2.4 RF Transfer Switch

3.2.4.1 Operating Modes

STPS-248 The RF Transfer Switch shall provide the capability to select the transmit path between the spacecraft omnidirectional antenna and spacecraft HGA systems.

3.2.4.2 RF Characteristics

3.2.4.2.1.1 Center Frequency

STPS-249 The RF Transfer Switch shall be capable of switching S-band signals at the transponder transmit frequency.

3.2.4.2.1.2 Bandwidth

STPS-250 The RF Transfer switch bandwidth shall include the range from 2.2 to 2.3 GHz.

3.2.4.2.1.3 VSWR

STPS-251 All ports shall have 50 ohm nominal impedance with a VSWR less than or equal to 1.1:1.

3.2.4.2.1.4 Insertion Loss and Isolation

STPS-252 Insertion Loss of the RF Transfer Switch shall be less than or equal to 0.2 dB.

STPS-253 Isolation of the RF Transfer Switch shall be greater than or equal to 55 dB.

3.2.4.3 Power Handling

STPS-254 The RF Transfer Switch shall be capable of handling the transmission of at least four (4) times the maximum transponder RF output power through the transmit channel, at the specified frequency, without degradation of performance.

STPS-466 The RF Transfer Switch shall not be damaged by intentional or unintentional switching of the transmit path with RF power present. Note that while the switch must be designed and tested to support this capability, "hot switching" is not the nominal mode of operation.

3.2.4.4 Corona and Multipaction

STPS-255 With four (4) times the maximum transmitter RF output power (i.e., 24W if the maximum transmitter RF output is 6W) applied to the RF Transfer Switch's input port at the transmit frequency, no evidence of corona or multipaction shall exist at any temperature within the specified operating range when the RF Transfer Switch is undergoing a pressure change from sea level to 10^{-5} torr or when the RF Transfer Switch is operated at critical pressure or in a hard vacuum.

STPS-256 This requirement (STPS-255) shall be verified by test, with the terminals of the RF Transfer Switch terminated by matched loads.

3.2.4.5 Time to Switch

STPS-257 The switching time, also specified as the RF Transfer Time, shall be less than 50 msec.

3.2.4.6 Input Voltage and Current

STPS-258 The nominal input voltage to any RF Transfer Switch control shall be 28 VDC, with a maximum current draw of 60 mA.

3.2.4.7 RF Switch Commanding

STPS-259 Control of the RF Transfer Switch shall be through a three wire interface: Side A, Side B, and Return.

STPS-260 Commands to change state of the RF Transfer Switch shall be +28 volts (V) (nominal) discrete pulses.

STPS-261 A +28V±7V pulse on the "Side A" control input shall change the switch to the Side A RF path.

STPS-262 A +28V±7V pulse on the "Side B" control input shall change the switch to the Side B RF path.

STPS-263 A constant +28V±7V signal (constant voltage) on either control input shall not stop the switch from responding to a command on the other control input. (A stuck "ON" command will not block a command to change to the "good" side).

STPS-264 The RF Transfer Switch shall respond to a minimum pull in voltage of 18V.

STPS-467 The RF Transfer Switch shall be designed to meet a minimum life of not less than five thousand (5000) cycles.

3.2.4.8 RF Switch Monitoring

STPS-265 Monitoring of RF Transfer Switch current state shall be through two sets of discrete outputs. The each switch state output will consist of two lines, connected to internal switch closures.

3.2.5 Directional Coupler

STPS-266 The Directional Coupler shall have a bandwidth that includes the range from 2.0 GHz to 2.3 GHz.

STPS-267 The Directional Coupler shall have a coupling factor of 6 dB.

3.2.5.1 Insertion and Coupling Loss

STPS-268 The Directional Coupler shall have an insertion loss of not greater than 0.2 dB in the "through" direction.

STPS-269 The Directional Coupler shall have a "coupling loss" of not greater than 0.5 dB.

3.2.5.2 Corona and Multipaction

STPS-270 With four (4) times the maximum transmitter RF output power (i.e., 24Ws if the maximum transmitter RF output is 6W) applied to the Directional Coupler at the transmit frequency, no evidence of corona or multipaction shall exist at any temperature within the specified operating range when the Directional Coupler is undergoing a pressure change from sea level to 10^{-5} torr or when the Directional Coupler is operated at critical pressure or in a hard vacuum.

STPS-271 This requirement (STPS-270) shall be verified by test, with the terminals of the Directional Coupler terminated by matched loads.

3.3 PHYSICAL CHARACTERISTICS

3.3.1 Mass Properties and Reporting

STPS-272 The supplier shall provide NASA with mass properties data.

STPS-273 The mass property data shall include mass and center of gravity estimates.

STPS-274 Final mass properties shall be provided at delivery, as per Section 4.2.5 of the Lunar Reconnaissance Orbiter S-Band Telemetry, Tracking, and Command Subsystem Statement of Work (431-SOW-000303).

3.3.1.1 Weight Limits

STPS-275 The integrated TT&C subsystem shall not exceed 8.8 kilograms (kg).

3.3.1.1.1 Transponder Mass

STPS-276 Total as delivered transponder mass shall be less than or equal to 5.0 kg.

3.3.1.1.2 Diplexer Mass

STPS-277 Total as delivered Diplexer mass shall be less than or equal to 1.2 kg.

3.3.1.1.3 RF Switch Mass

STPS-278 Total as delivered RF Transfer Switch mass shall be less than or equal to 0.2 kg.

3.3.1.1.4 Directional Coupler Mass

STPS-279 Total as delivered Directional Coupler mass shall be less than or equal to 0.1 kg.

3.3.1.1.5 RF Cabling Mass

STPS-280 Total as delivered mass of cabling, harness, and component interconnects shall be less than or equal to 1.0 kg.

3.3.2 Center of Mass

STPS-281 The contractor shall define the center of mass. The center of mass of each component shall be determined to within ±2.5 millimeters (mm) relative to an external reference.

3.3.3 Mechanical Envelope

STPS-282 For the purposes of clarifying this requirement, the length and width dimensions define the mounting surface and the height and length dimensions define the connector face. See Figure 3-5 below:

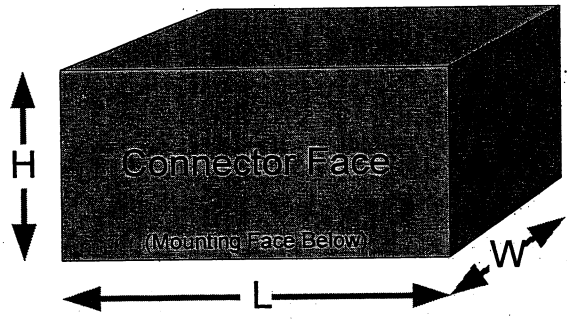


Figure 3-5. Envelope Dimension Definitions

The Contractor may deliver the integrated subsystem as a single unit, or multiple units mounted on a common interface plate. All requirements apply equally to either integrated or multiple assembly mechanical configurations. Subsystem mechanical configuration will be detailed in the Lunar Reconnaissance Orbiter S-Band Transponder Mechanical Interface Control Document (431-ICD-000375).

3.3.3.1 Transponder Mechanical Envelope

STPS-283 Overall dimensions of the Transponder, excluding mounting feet, manufacturing tolerances, and connectors, shall be limited to the following: 20.0 centimeters (cm) (length) x 20.0 cm (width) x 20.0 cm (height).

3.3.3.2 Diplexer Mechanical Envelope

STPS-284 Overall dimensions of each Diplexer, excluding mounting feet, manufacturing tolerances, and connectors, shall be limited to the following: 13.0 cm (length) x 14.0 cm (width) x 5.0 cm (height).

3.3.3.3 RF Switch Mechanical Envelope

STPS-285 Overall dimensions of the RF Switch, excluding mounting feet, manufacturing tolerances, and connectors, shall be limited to the following: 10.0 cm (length) x 7.0 cm (width) x 5.0 cm (height).

3.3.3.4 Directional Coupler Mechanical Envelope

STPS-286 Overall dimensions of the Directional Coupler, excluding mounting feet, manufacturing tolerances, and connectors, shall be limited to the following: 10.0 cm (length) x 2.0 cm (width) x 2.0 cm (height).

3.3.4 Connectors

STPS-287 External box connectors shall be chosen from those in the Instructions for EEE Parts Selection, Screening, Qualification, and De-rating (EEE-INST-0002). If the component requirements cannot be met using one of these connectors, equivalent alternates may be used if it meets the derating criteria of Instructions for EEE Parts Selection, Screening, Qualification, and De-rating (EEE-INST-0002), or after successful completion of a qualification program based upon theguidelines contained therein.

STPS-288 Information for all connectors in the TT&C Subsystem shall be included in the Lunar Reconnaissance Orbiter S-Band Electrical Interface Control Document (431-ICD-000374) and the Lunar Reconnaissance Orbiter S-Band Mechanical Interface Control Document (431-ICD-000375).

3.3.4.1 Transponder Connectors

STPS-289 The Transponder shall have the following connectors: Receiver Power, Transmitter Power, Serial UART Control Port, Auxiliary Command Interface, C&DH Telemetry/Command Interface, Receiver RF Uplink Port, and Transmitter RF Downlink Port.

STPS-290 The Transponder Receiver power connector shall interface the Transponder with the power bus through a DB9 male connector with the pinout as specified in Table 3-12.

Table 3-12. Receiver Power Connector

Pin Number	Pin Designation
1	Power (PWR)
2	PWR
3	No Connect (NC)
4	PWR
5	PWR
6	Ground (GND)
7	GND
8	GND
9	GND

STPS-291 The Transponder Transmitter power connector shall interface the Transponder with the power bus. This connector shall be DB9 male connector with the pinout as specified in Table 3-13.

Table 3-13. Transmitter Power Connector

Pin Number	**Pin Designation**
1	PWR
2	PWR
3	NC
4	PWR
5	PWR
6	GND
7	GND
8	GND
9	GND

STPS-292 The Serial UART Control Port connector shall contain the UART Transmit and UART Receive signals, as well as the associated signal returns.

STPS-293 The C&DH Telemetry / Command Interface shall contain the symbol and symbol timing signals between the Transponder and the C&DH including the received data and received data timing clock, outbound symbols (spacecraft telemetry) and outbound symbol timing clock. These signals are differential RS-422. Also included in this connector are the necessary signal grounds.

STPS-294 The Transponder Auxiliary Command Interface shall contain the Auxiliary Command Interface baseband differential signal and the Auxiliary Command Enable lines. Connection to the Auxiliary Command Interface baseband signal will be by shielded, twisted pair. The Auxiliary Command Enable connects to an external switch closure.

STPS-295 The two pins of the Auxiliary Command Interface and the Auxiliary Command Interface Enable shall have no greater than 1 mega ohm to a control voltage or ground to preclude on-orbit charging/discharging due to the space plasma environment

STPS-296 The baseband Aux Command and Aux Command Enable lines shall be designed with transient protection in the event of a nearby lightning strike during ELV pad operations as lightning can induce transient energy into the spacecraft wiring, especially the spacecraft umbilical cable(s).

Of concern is circuit damage due to induced lightning. RTCA-DO160E, Section 22 specifies indirect lightning waveforms, levels and test method including setup and calibration procedures as specified below. Note verification by analysis only is acceptable, there is no required active transient suppression testing.

At the launch complex, assume a Level 3 environment (intended for equipment and interconnecting wiring in a moderately exposed electromagnetic environment).

Table 3-14. RTCA-DO160E Induced Lighting Transient Waveforms

Level	Waveform 3 Voc/Isc *	Waveform 4 Voc/Isc **
3	600/24	300/60

* See RTCA-DO160E Figure 22-4 for Waveform 3, which is a damped sine, 1 MHz of RTCA-DO160.

** Waveform 4 is a unipolar pulse with T1 = 6.4 microseconds and T2 = 69 microseconds as shown in RTCA-DO160E Figure 22-5.

** Voc represents the open circuit test generator voltage in Volts and Isc represents the generator short circuit current in Amperes.

STPS-297 The Transponder Receiver RF Uplink port shall be coaxial SMA female.

STPS-298 The Transponder Transmitter RF Downlink port shall be coaxial SMA female.

3.3.4.2 RF Transfer Switch Connectors

STPS-299 The control and status connector for the RF Transfer Switch shall be determined by the vendor.

STPS-300 The RF signal connectors of the RF Transfer Switch including Side A, Side B, and Common shall be coaxial SMA female.

3.3.4.3 Diplexer Connectors

STPS-301 The RF signal connectors on the Diplexer shall be coaxial SMA female.

3.3.4.4 Directional Coupler Connectors

STPS-302 The RF signal connectors on the Directional Coupler shall be coaxial SMA female.

3.3.4.5 Mounting

STPS-303 All components of the TT&C subsystem assembly shall operate as specified herein when mounted in any orientation.

STPS-304 The mounting interface shall be defined in the appropriate component Mechanical ICD.

3.4 ELECTRICAL REQUIREMENTS

3.4.1 Power

3.4.1.1 Component Power Input Voltage

STPS-305 All active components shall meet all performance requirements with prime power input between 21 and 35 VDC at its primary power input. The nominal power input is 28 VDC.

3.4.1.2 Component Power Consumption

3.4.1.2.1 Transponder Power Consumption

STPS-306 The maximum power draw for the transponder shall be 12Ws when the transmitter section is OFF. (This is the power to operate the command receiver, power supply, C&DH interface and baseband processing only)

STPS-307 The maximum power draw for the transponder shall be 47W when the transmitter section is ON. (This is the power to operate the complete transponder in a full duplex mode).

STPS-308 The transponder shall provide independent primary and secondary power inputs for the transmitter and receiver sections. (Two independent inputs for transmitter power, and two independent inputs for receiver power)

3.4.1.2.2 RF Transfer Switch Power Consumption

STPS-309 The maximum power draw for the RF Transfer Switch shall be 1.7W when changing RF paths through the switch.

STPS-310 The RF Transfer Switch shall not consume DC power when in a quiescent state (e.g., when no switch command pulse is present at the inputs).

3.4.1.3 Maximum Sustained Input Current

STPS-311 The subsystem's peak input current during operation shall not exceed 1.9 ampere (A) from either service. The peak current draw requirement can be met through the use of a phased power-up scheme.

3.4.1.4 Power System Electronics Output Switching Profile

STPS-312 The component shall survive without degradation the following power switching profiles:

When a service is switched on, the voltage will rise from 0 to the steady-state voltage no faster than 50 microseconds to reduce the in-rush at the user circuitry.

When a service is switched on, the voltage will rise from 0 to the steady-state voltage no slower than 3ms to allow for proper operation of power-on reset circuitry.

When a service is switched off or trips off due to a fault condition, the voltage will fall to 0 V no faster than 20 microseconds, prohibiting a sharp turn-off from producing an induced electromagnetic interference (EMI) emission.

Minimum turn on time reduces in-rush current. Maximum turn on time allows proper operation of power-on reset circuitry. Minimum turn off time reduces induced EMI emission. These are the characteristics of the power supply circuitry.

3.4.1.5 Turn-on Transients (In-Rush Current)

The spacecraft PSE utilizes SSPC devices to control the power. Unlike the electromechanical switches, the solid-state power switch devices control the turn-on time by limiting the input voltage rise time. The typical turn-on time of a solid-state power switch device is between 50 and 200 microseconds. The input voltage rises linearly with respect to the turn-on time. This delay may eliminate the need for a subsystem to employ an active means for reducing in-rush

current at their power input. The subsystem should plan, analyze and test to verify that a current limiter is not required.

STPS-313 The LRO component transient in-rush current shall be within the following limits as listed below and as provided in Figure 3-6 below for a 2A service.

STPS-314 If the inrush current is measured with an electromechanical device as the input power switching device, the inrush current of a component shall not exceed a rate of change of 1A per microsecond in the first 10 microseconds.

STPS-315 If the inrush current is measured with an electromechanical device as the input power switching device, the inrush current of a component shall not have a maximum rate of change of greater than or equal to 20 mA/microseconds after the initial 10 microseconds surge.

STPS-316 If the inrush current is measured with an electromechanical device as the input power switching device, the component transient current shall never exceed 300% of the maximum steady-state current in the first 10ms.

STPS-317 If the inrush current is measured with an SSPC as the input power switching device, the inrush current of a component shall not exceed a rate of change of 200 mA/microseconds until the voltage reaches the nominal level.

STPS-318 If the inrush current is measured with an SSPC as the input power switching device, the inrush current of a component shall not exceed a rate of change of 20 mA/ microseconds after the voltage reaches the nominal level.

STPS-319 If the inrush current is measured with an SSPC as the input power switching device, the transient current shall never exceed 300% of the rated output current of the SSPC in the first 70ms.

STPS-320 In-rush current shall be reduced to nominal load at 100 ms after turn-on.

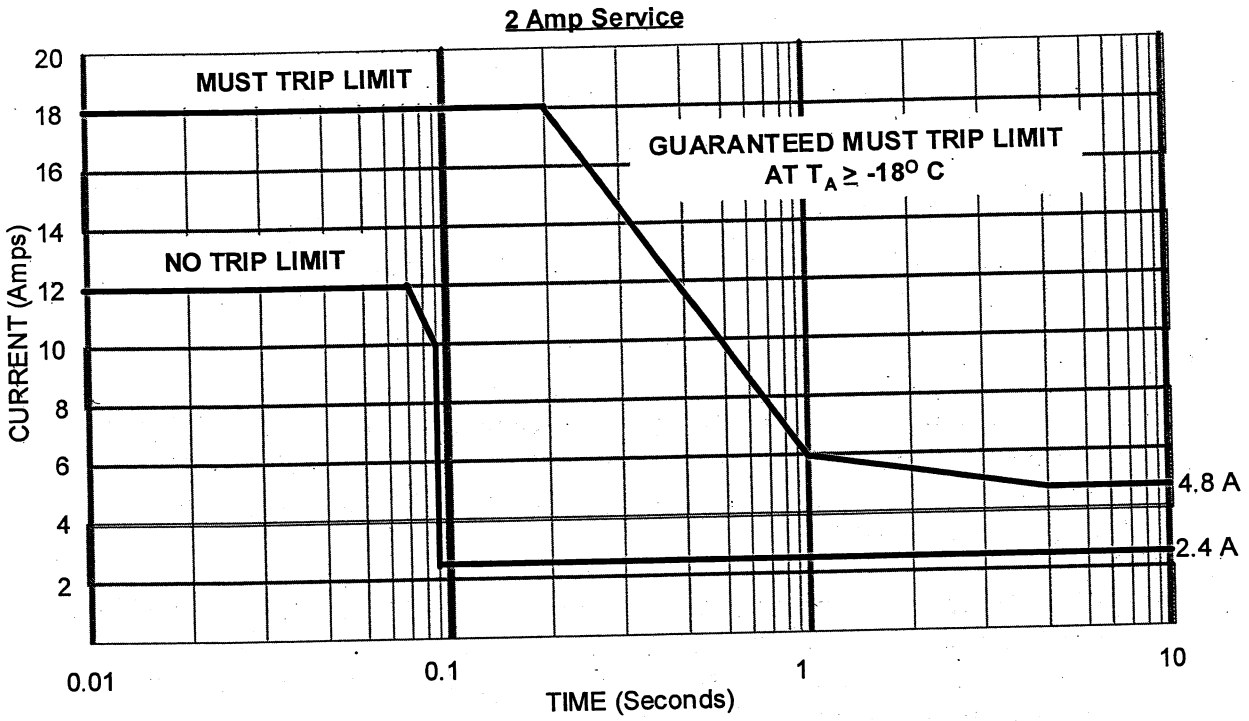


Figure 3-6. SSPC In-rush and Trip Current Limits Curve for 2 Amp Service

3.4.1.6 Survival of Anomalous Voltage

STPS-321 The component shall be designed to not be damaged by any voltage in the range of 0 to +40 VDC for an indefinite time period applied to the power input during anomalistic operations. No flight component will be subjected to these tests. Anomalies during ground testing can result in such conditions.

STPS-322 Verification shall be by analysis or test on an ETU or at a board level only.

If the component includes parts that are not guaranteed to perform down to 0 VDC, anomalous voltage analysis or test low limit shall be:

a. lowest voltage guaranteed by manufacturer of that component or

b. low voltage that corresponds to the maximum sustainable current for that component's switched service, whichever is lower

All components shall meet performance requirements during the single-event transient (SET) of +/- 3.0V superimposed on the power bus described in 3.4.1.9 below.

3.4.1.7 Ripple

STPS-323 The component shall meet operational performance requirements in the presence of ripple as described in Conducted Susceptibility (CS) 01/CS02 testing in Section 3.4.3.4.1.

3.4.1.8 Operational Bus Transients

STPS-324 The rate of change of any operational current transients shall not exceed 20 mA/ microseconds.

3.4.1.9 Single-Event Power Bus Transients

STPS-325 Single-event power bus transients superimposed on the power bus due to normal component load switching shall be limited to +/-3.0V from the steady-state bus value. An example of this would be a subsystem that controls its own loads, turning them on and off.

The bus will recover to within 10% of its steady state value in 10ms for a positive or negative load step of 10A with a maximum current rate change of 50 mA/ microseconds. The bus will recover to within 10% of its steady state value in 50ms for a positive or negative load step of 15A with a maximum current rate change of 300 mA/microseconds.

3.4.1.10 Turn-Off Transients

STPS-326 When the power service is switched off, the peak voltage transients induced on the power service shall not exceed +40V, nor fall below -1V.

3.4.1.11 Turn-Off Protection

STPS-327 The component shall not be damaged by the unannounced removal of power.

STPS-328 Any operations required on a routine basis prior to power turn off shall be listed in the component ICD.

STPS-329 Any minimum time following power turn-off that the component must remain off prior to power turn-on shall be listed in the ICD.

3.4.1.12 Polarity Reversal Protection

STPS-330 The component shall not be damaged by polarity reversal of the input power.

3.4.1.13 Subsystem Over-Current Protection

STPS-331 The component shall not use non-resetting over-current protection (i.e., fuses) internal to the component.

3.4.1.14 Component Power Redundancy

STPS-332 The component shall provide redundant prime power and prime power return lines. The spacecraft will provide power over both sets of lines simultaneously.

3.4.1.15 Redundant Power Supplies

STPS-333 The component shall not be damaged by the simultaneous application of power to both power supply inputs.

3.4.2 Grounding

3.4.2.1 Primary Input Isolation

STPS-334 At the component primary power interfaces, primary power (28 VDC) and primary power returns shall be isolated from the component chassis by greater than or equal to 1 Megohms (Mohms) DC.

3.4.2.2 Secondary Ground

STPS-335 The secondary return (power, signal, analog, or digital grounds) shall be locally connected to the component chassis with low impedance paths (<= 2.5 milliohms DC per joint) to minimize stray current.

STPS-336 Both secondary power (or signal) inputs and returns shall be isolated from primary power by equal to or greater than 1 Mohms DC.

3.4.2.3 Common Mode Noise

STPS-337 Common mode noise for the primary and secondary power, as well as digital, analog and signal grounds, shall be less than 100 millivolts (mV) p-p.

3.4.2.4 Bonding or Mating

STPS-338 The primary mating method for a component shall be the metal-to-metal contact between component mounting feet (or baseplate) and the LRO structure. Mating (electrically bonding) surfaces should be free from nonconductive finishes and should establish at least 80 square mm of contact area.

STPS-339 The electrical DC resistance of a mechanical contact between two conductive mating surfaces shall not exceed 5 milliohms DC.

3.4.2.5 Grounding of Conductors

STPS-340 All conductors shall be grounded to the spacecraft structure, with no floating conductors.

3.4.2.6 Grounding of External Surfaces

STPS-341 All external surfaces shall be grounded. Where this is not possible, it will be identified in the individual component Electrical ICD.

3.4.2.7 Connector Grounding

STPS-342 Component connectors and backshells shall be electrically mated to the chassis through an electrical resistance not exceeding 5 milliohms DC.

3.4.3 Electromagnetic Interference and Electromagnetic Compatibility

3.4.3.1 Test Methods

STPS-343 The EMI/electromagnetic compatibility (EMC) test methods shall be per the requirements of MIL-STD-462C (Notice 6) unless noted in this document.

3.4.3.2 Conducted Emissions (CE01/CE03)

3.4.3.2.1 CE01/CE03

STPS-344 Conducted emissions (CE) from the component shall not exceed the values shown in the figure below when subjected to CE01 (20 Hz - 14 kHz) and CE03 (14 kHz - 40 MHz) narrowband testing.

STPS-345 All tests shall be performed in ambient with the component in its most sensitive mode for susceptibility testing and in its most noisy mode as appropriate for the EMI emission test.

STPS-346 CE01/CE03 shall be performed on all +28V primary power and return lines to each component.

STPS-347 CE01/CE03 shall be performed in differential and common mode.

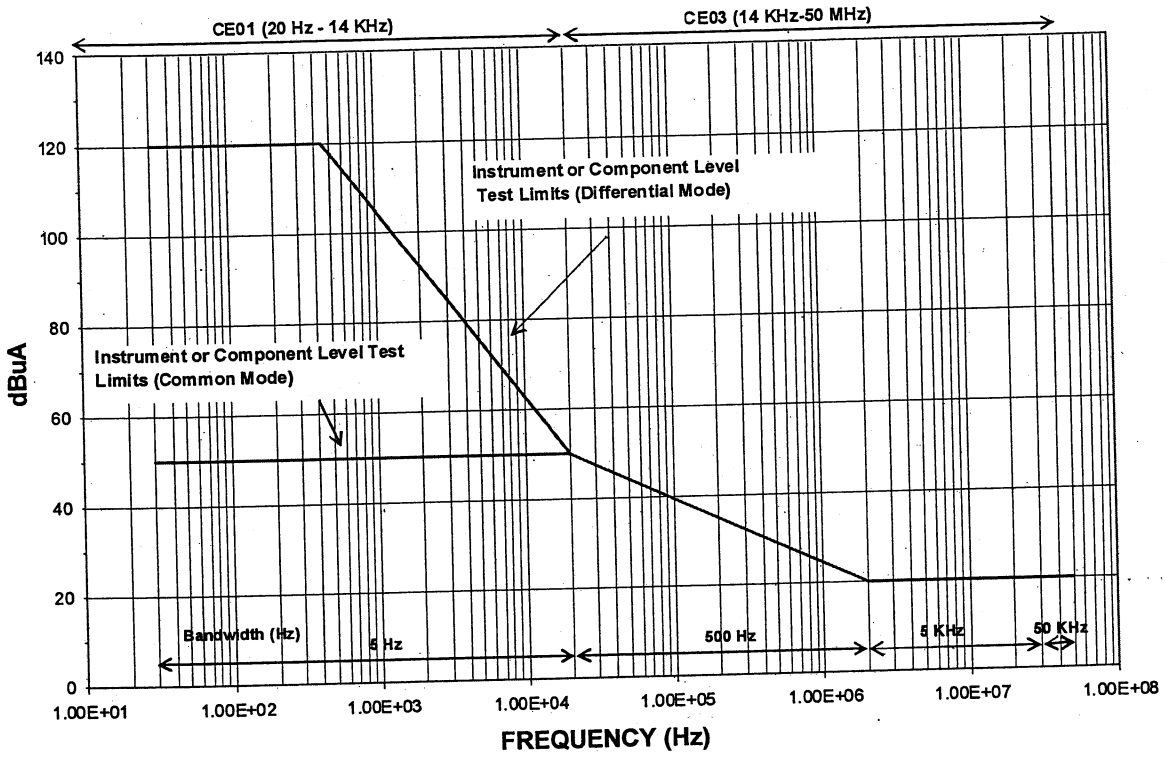


Figure 3-7. Narrowband Conducted Emissions CE01/CE03 Limits

3.4.3.2.2 CE06

STPS-348 . All RF receivers and transmitters shall perform the additional CE06 EMI test to the limits contained in MIL-STD-461C.

3.4.3.3 Radiated Emissions (RE02)

STPS-349 Radiated emissions (RE) from the component shall not exceed the values shown in the appropriate figure below when subjected to RE02 narrowband testing.

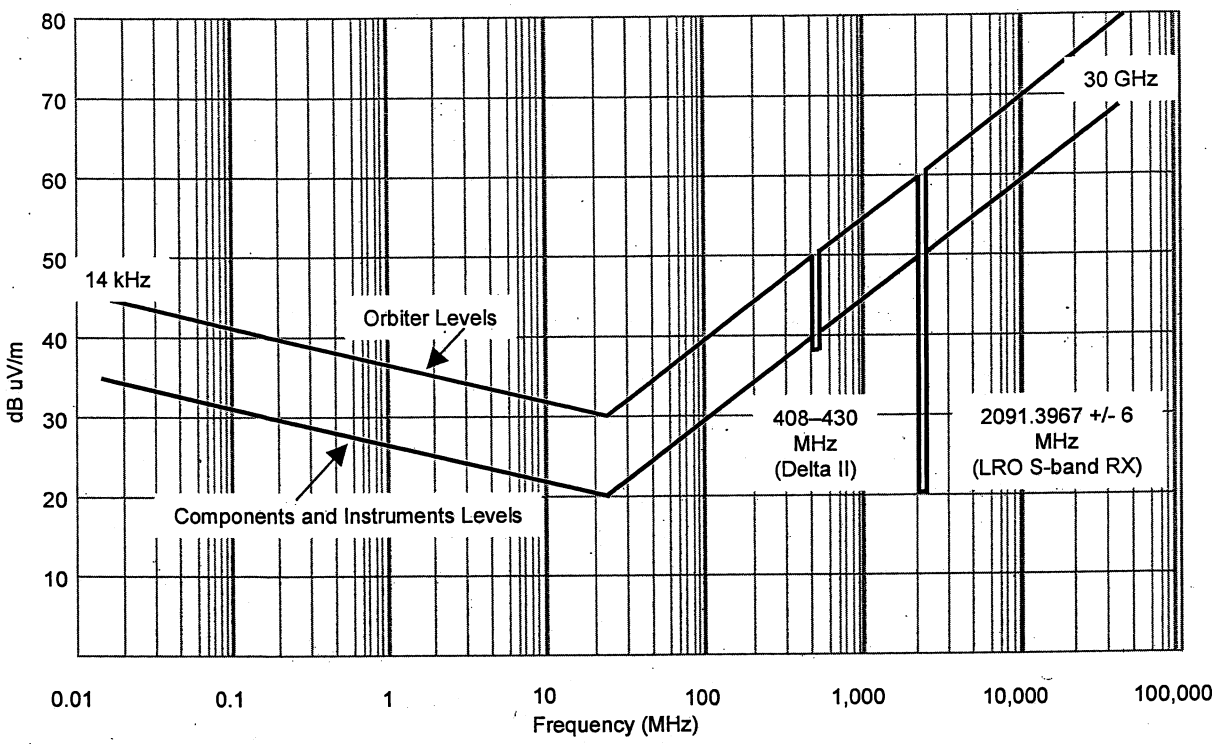


Figure 3-8. RE02 Limits for the Orbiter and Components that are ON from launch to vehicle separation

3.4.3.4 Conducted Susceptibility

STPS-350 Undesirable response, malfunction, or degradation of performance shall not be produced in the component during CS testing with the tests specified below.

3.4.3.4.1 CS01/CS02

STPS-351 The CS01 and CS02 (injection of energy into power lines) shall be performed on all electronics that contain the DC/DC converters or power regulation devices.

STPS-352 The CS01 test limits shall be 3.1 V RMS at the frequency range of 30 Hertz (Hz) to 1.5 kHz, and ramping in a straight line down to 1.0 volt at 50 kHz.

STPS-353 The CS02 limit for the test shall be 1.0 V RMS at the frequency range of 50 KHz to 400 MHz. These limits, which are defined by MIL-STD-461C, are shown in the figure below.

STPS-354 The CS01 and CS02 (injection of energy into power lines) performance shall be verified at the nominal +28V only.

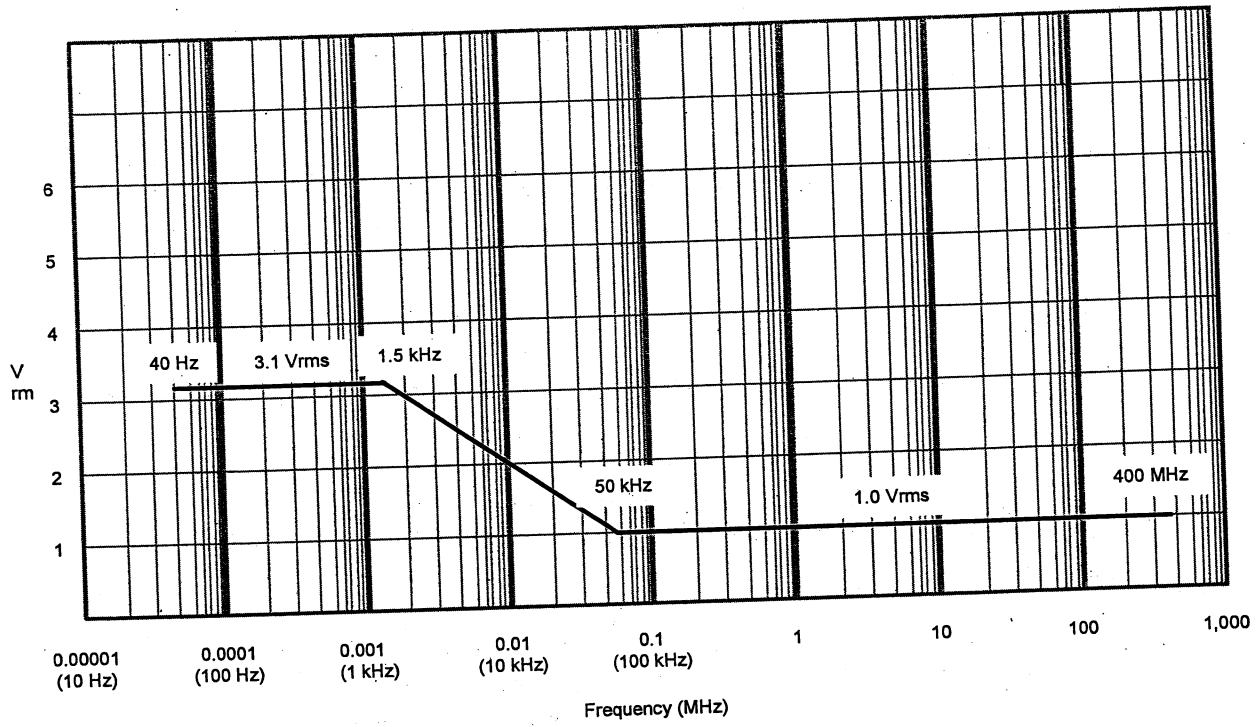


Figure 3-9. CS01/CS02 Limits

3.4.3.4.2 CS03

STPS-355 The CS03 (Two Signal Intermodulation) test shall be performed on all RF receiving electronics.

STPS-356 The CS03 (Two Signal Intermodulation) test performed on all RF receiving equipment shall not cause the RF equipment to exhibit any intermodulation products from two input signals, beyond those permitted in the RF electronics specification.

STPS-357 The CS03 test for RF receiving electronics shall be conducted per MIL-STD-462 to the limits specified in the General Environmental Verification Specification (GEVS) for GSFC Flight Programs and Projects (GSFC-STD-7000).

3.4.3.4.3 CS04

STPS-358 The CS04 (Rejection of Undesired Signals) test shall be performed on all RF receiving electronics.

The CS04 (Rejection of Undesired signals) test for RF receiving electronics consists of a 0.0 dBm (1 milliwatt [mW]) signal applied directly to the receiver input terminals and notched around the receiver input bandwidth at 80.0 dB above its threshold.

STPS-359 The input notch center shall be at the receiver-tuned frequency and in the center of the notch.

STPS-360 The CS04 test for RF receiving electronics shall be conducted per MIL-STD-461C to the limits specified in the General Environmental Verification Specification (GEVS) for GSFC Flight Programs and Projects (GSFC-STD-7000).

3.4.3.4.4 CS05

STPS-361 The CS05 (Cross Modulation) test shall be performed on all RF receiving electronics.

STPS-362 The CS05 (cross-modulation) test performed on all RF receiving electronics shall not cause the RF equipment to exhibit any cross-modulation from two input signals.

STPS-363 The CS05 test for RF receiving electronics shall be conducted per MIL-STD-461C to the limits specified in the General Environmental Verification Specification (GEVS) for GSFC Flight Programs and Projects (GSFC-STD-7000).

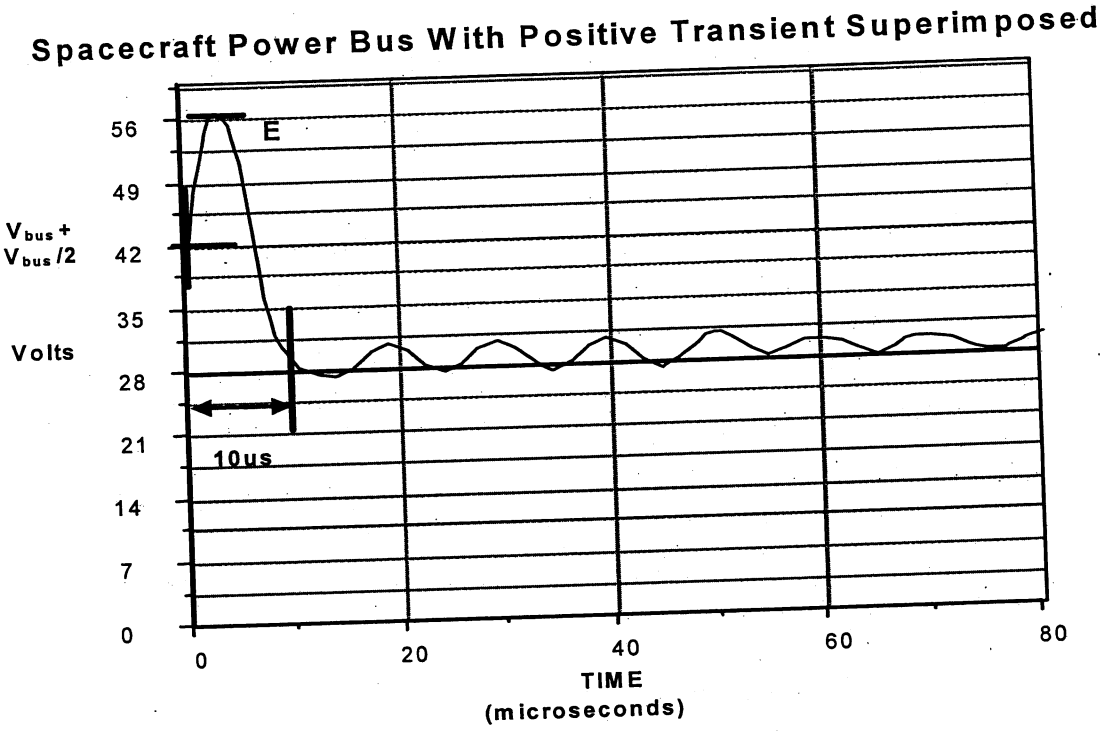
3.4.3.4.5 CS06

STPS-364 The CS06 (Powerline Transient) shall be performed on all electronics that contain DC/DC converters or power regulation devices.

The CS06 (Powerline Transient) test consists of both a positive transient test and a negative transient test, having amplitude of +28V superimposed on the +28V power bus as shown in Figure 3-10.

STPS-365 This pulse shall be limited to +56V peak absolute value and 10 microseconds from 0.5E (42V) to the +28V steady-state value crossing point as shown in the figure below.

CS06 Test



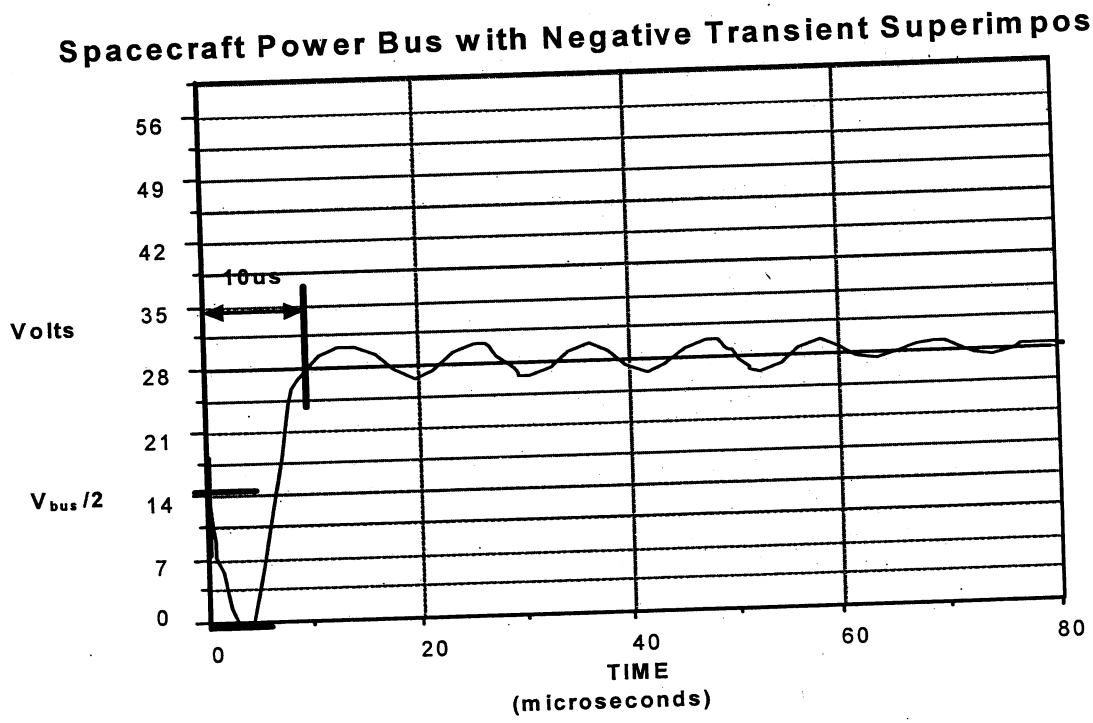


Figure 3-10. CS06 Conducted Susceptibility Test Pulse

3.4.3.5 Radiated Susceptibility (RS03)

STPS-366 Undesirable response, malfunction, or degradation of performance shall not be produced during component Radiated Susceptibility (RS) testing with the E-field levels shown in the table below.

Table 3-15 LRO Operational RS Test Limits

Frequency Range	Test Level	Requirement Source
14 KHz - 2 GHz	2 V/m	GSFC-STD-7000
2 GHz - 12 GHz	5 V/m	GSFC-STD-7000
12 GHz - 28 GHz	10 V/m	GSFC-STD-7000
2271.2 MHz +/- 5 MHz	7 V/m	LRO S-Band Transmitter
25.5 GHz - 28.0 GHz	10 V/m	LRO Ka-Band Indirect Radiation

STPS-367 The component shall survive the RS test levels of the launch site transmitters shown in the table below.

Table 3-16. Launch Site/Vehicle RS Test Levels

Frequency (Hz)	E-field (V/m)
1.40E+04	20
2.20E+09	20
2.20E+09	47.7
2.50E+09	47.7
2.50E+09	20
5.60E+09	20
5.60E+09	91
5.90E+09	91
5.90E+09	20
1.20E+10	20
1.20E+10	5
4.00E+10	5

3.4.4 Data and Signal Interfaces

STPS-368 The presence or absence of any combination of the input signals applied in any sequence shall not cause damage to the component, reduce its life expectancy, or cause any malfunction, whether the component is powered or not.

3.4.4.1 Inter-Component Communications

STPS-369 Components connected using RS-422 differential signals shall adhere to the electrical terminations as given in the Electrical Characteristics of Balanced Voltage Digital Interface Circuits (TIA/EIA-422).

3.4.4.1.1 +28 V Discrete Command Interfaces

The +28V discrete pulse command will be used to actuate relays or other non-digital actuators.

STPS-370 The discrete command pulse circuit shall be designed to minimize coupling of the actuator switching noise into the digital or logic portion of the electronics.

Unregulated +28 VDC from the PSE may be used to generate the +28V pulse command; however, the isolation requirements between primary power and secondary power (logic power) of 1 Mohm shall always be maintained.

3.4.4.1.2 Other Inter-Component Communications

STPS-371 Other component interfaces not specified in this section shall be identified in the specific applicable component Electrical ICD.

3.4.4.2 Component Test Interfaces

STPS-372 All test points shall be protected or isolated from the facility-induced noise, electrostatic discharge (ESD), and ground support equipment (GSE) malfunction.

STPS-373 GSE cable connectors that mate with flight test connectors shall be flight-approved connectors.

STPS-374 Test connectors shall be capped with flight-approved RF and static control covers when not in use, including in orbit.

STPS-375 Wherever possible, component power shall not be applied or accessed at or through a test connector.

Test signals and flight signals should not be located together in the same connector.

3.4.5 Multipaction and Corona

STPS-376 Components with high-voltage circuits shall be immune to corona and arcing while in a nominal orbital vacuum environment.

STPS-377 Damage or measurable degradation due to RF breakdown (corona and arcing) shall be prevented by design.

STPS-378 The RF design shall preclude measurable degradation due to multipaction and corona in RF systems that must operate during the launch and ascent stages (e.g., filters, switches, and antenna elements), at critical pressures, or in a vacuum environment.

STPS-379 Individual components of the S-Band TT&C Subsystem shall meet the corona and multipaction requirements of Sections 3.2.2.6, 3.2.3.4, 3.2.4.4, 3.2.5.2, and 3.2.6.2.

3.4.6 Charging Mitigation

STPS-380 External surfaces >6 cm2 shall be conductive with a resistivity of less than 109 ohms per square (ohms/sq.) and grounded to the component chassis.

STPS-381 Insulating films such as Kapton and other dielectric materials on the external surface shall be less than 5 mil thick and assembled to minimize surface charge build-up and grounded to bleed surface charge.

STPS-382 System impacts of the discharges from any unavoidable non-conductive surfaces shall be assessed and approved. If necessary, a waiver request will be submitted for each specific non-compliant application.

STPS-383 The contractor shall supply a comprehensive list of non-conductive surfaces on the outside of the component.

STPS-384 Ungrounded (floating) conductors shall not be allowed in the Orbiter. This includes unused wires in harnesses; ground test sensors; ground use signals in cables; unused or unpopulated circuit board traces; ungrounded integrated circuit (IC), relay, transistor, or capacitor cases; spare pins in connectors; thermal blankets; aluminum or copper tape; ungrounded bracketry for harness or connectors; TC105 harness tie-down clips; harness P-clamps; conductive epoxy; thermostat cases; screws; or nut plates. Exceptions are allowed by waiver if analysis shows that no direct or radiated path to victim circuitry exists or that the victim can survive discharge.

STPS-385 Leakage impedance of conductive internal parts shall be less than 10,000 ohms. This requirement applies to conductive fittings on dielectric structural parts.

STPS-386 The transmitter, receiver, and antenna system shall be tested for immunity to ESD near the antenna feed.

3.4.7 Harness Requirements

STPS-387 Qualified wire, cable, and connectors specified in the Instructions for EEE Parts Selection, Screening, Qualification, and Derating (EEE-INST-002) shall be used for any of the component harnesses.

STPS-388 Wires, connectors, connector contacts, and other harness piece parts shall be derated per the Instructions for EEE Parts Selection, Screening, Qualification, and Derating (EEE-INST-002).

3.4.8 Connectors

3.4.8.1.1 Accessibility

STPS-389 The component connectors, on each box, shall be spaced far enough apart to access the harness connector with EMI backshells by a hand or with an extraction tool. Any harness cable or connector should not touch any other adjacent connectors or harnesses.

3.4.8.1.2 Sizing

STPS-390 All connectors on a component shall be different sizes, pin counts and/or genders to prevent any mismating of harness to component connectors.

3.4.8.1.3 Keying

STPS-391 Wherever possible, keying shall be used.

3.4.8.1.4 Connector Savers

STPS-392 Connector savers shall be used during integration and test to minimize wear on connector contacts.

3.4.8.1.5 Mate/Demate Logs

STPS-393 Connector mate/demate logs shall be used to record mates and demates.

3.4.8.1.6 Connector List

STPS-394 The component contractor shall provide a list of connectors prior to connector part procurement.

3.4.8.1.7 EMI Backshell

STPS-395 All component input/output (I/O) connector interfaces shall be designed to accommodate an EMI backshell.

3.4.8.1.8 Separation of Signals

STPS-396 If possible, the power and signal should not share the same connectors.

3.4.8.1.9 Connector Gender

STPS-397 The connector half that sources power to another component shall be female (socketed) to protect against inadvertent grounding prior to mating.

3.5 RADIATION REQUIREMENTS

3.5.1 Introduction

This section gives the Total Ionizing Dose (TID), non-ionizing Displacement Damage Dose (DDD), and Single Event Effects (SEE) requirements for the LRO. In this section, it is assumed that a top-level shielding requirement of at least 100 mils equivalent aluminum shielding between all parts and free space. That is, there must be 100 mils equivalent aluminum shielding in all solid angles projected from the part out towards free-space. The requirements below assume that shielding for each part meets this minimum shielding requirement.

Note that the spacecraft bus provides shielding equivalent to 20 mils of aluminum to all internally mounted components.

3.5.1.1 Definitions

Single Event Upset (SEU) - a change of state or transient induced by an energetic particle such as a cosmic ray or proton in a device. This may occur in digital, analog, and optical components or may have effects in surrounding interface circuitry (a subset known as Single Event Transients [SETs]). These are "soft" errors in that a reset or rewriting of the device causes normal device behavior thereafter.

Single Hard Error (SHE) - a SEU that causes a permanent change to the operation of a device. An example is a stuck bit in a memory device.

Single Event Latchup (SEL) - a condition that causes loss of device functionality due to a single event induced high current state. A SEL may or may not cause permanent device damage, but requires power cycling of the device to resume normal device operations.

Single Event Functional Interrupt (SEFI) - a condition that causes loss of device functionality due to a single event in a device control register. It generally requires a device reset to resume normal device operations, but, for some devices, a power cycle is necessary to resume normal device operations.

Single Event Burnout (SEB) - a condition that can cause device destruction due to a high current state in a power transistor.

Single Event Gate Rupture (SEGR) - a single ion induced condition in power MOSFETs that may result in the formation of a conducting path in the gate oxide.

Single Event Effect (SEE) - any measurable effect to a circuit due to an ion strike. This include (but is not limited to) SEUs, SETs, SHEs, SELs, SEFIs, SEBs, SEGRs, and Single Event Dielectric Rupture (SEDR).

Multiple Bit Upset (MBU) - an event induced by a single energetic particle such as a cosmic ray or proton that causes multiple upsets or transients during its path through a device or system.

Linear Energy Transfer (LET) - a measure of the energy deposited per unit length as an energetic particle travels through a material. The common LET unit is MeV*cm^2/milligram (mg) of material (International System of Units [Si] for Metal Oxide Semiconductor [MOS] devices, etc.).

Threshold LET (LET_{th}) - the minimum LET to cause an effect at a particle fluence of 1E7 ions/cm^2. Typically, a particle fluence of 1E5 ions/cm^2 is used for SEB and SEGR testing.

3.5.2 Total Ionizing Dose

STPS-398 No effect due to TID shall cause permanent damage to, or degradation of the component.

STPS-399 All parts shall be assessed for sensitivity to TID effects.

STPS-400 If part test data do not exist, ground testing shall be required.

STPS-401 For commercial parts, testing shall be required on the flight procurement lot.

STPS-402 All testing shall be Cobalt-60 (Co-60) testing as per Test Method Standard, Microcircuits (MIL-STD-883 Method 1019.6).

STPS-403 For any part that is estimated to have on-orbit performance degradation due to TID, an analysis shall be performed to show that this degradation does not cause damage to or induce degradation of the component performance.

3.5.2.1 Total Ionizing Dose Environment Specifications

STPS-404 The TID requirement shall be 10.8 krad-Si. If high dose rate archival data are used for considering TID sensitivity of any particular linear bipolar or Bipolar Complementary Metal Oxide Semi-Conductor (BiCMOS) part, the TID requirement is 37.8 krad-Si.

STPS-405 If a part's performance degradation due to TID is not acceptable using the top-level requirements, then the space radiation environments shall be estimated using a 3 dimensional Monte Carlo analysis or a ray trace analysis. The table below shows the mission dose level requirement as a function of aluminum shielding thickness.

Note that the spacecraft bus provides shielding equivalent to 20 mils of aluminum to all internally mounted components.

Table 3-17. Mission Dose requirement versus Al Shield Thickness

Al shield Thickness (mils)	Mission dose (krad-Si)
100	10.8
150	6.4
200	4.6
300	2.6

3.5.3 Part Displacement Damage Dose Specification

STPS-406 No effect due to DDD shall cause permanent damage to or degradation of the component.

STPS-407 Each part shall be assessed for potential sensitivity to DDD effects.

STPS-408 For those parts deemed sensitive to DDD, if part test data do not exist, ground testing shall be required.

STPS-409 For commercial parts, testing shall be required on the flight procurement lot.

STPS-410 All testing shall be performed using protons to a mission equivalent fluence.

STPS-411 For any part that is estimated to have on-orbit performance degradation due to DDD, an analysis shall be performed to show that this degradation does not cause damage to or induce degradation of the component performance.

3.5.3.1 Displacement Damage Dose Environment Specifications

STPS-412 The top level DDD requirement for parts shall be 2.7E10 protons/cm2 of 10 Mega-electron Volts (MeV) protons.

STPS-413 Alternative proton energies can be used for test and analysis. The requirement shall be scaled according to the Non Ionizing Energy Loss (NIEL).

3.5.4 Single Event Effects Specification

3.5.4.1 Part Single Event Effects Specification

STPS-414 No SEE shall cause damage to a component or induce performance anomalies or outages that require ground intervention to correct.

STPS-415 If part test data do not exist, ground testing shall be required.

STPS-416 For commercial parts, testing shall be required on the flight procurement lot.

STPS-417 Immunity shall be defined as a LETth > 75 MeVcm2/mg.

STPS-418 For any part that is not immune to SEL, an analysis shall demonstrate that the SEL probability of occurrence is negligible in the LRO mission environment.

STPS-419 All N channel power Metal Oxide Semiconductor Field-Effect Transistors (MOSFETs) may be susceptible to SEB in the off mode. N channel MOSFET shall be evaluated at the worst-case application.

STPS-420 The survival V Drain-Source (VDS) voltage shall be established from exposure to minimum fluence of 1E6 ions/cm2 with a minimum LET of 26 MeVcm2/mg and a range that is sufficient to penetrate the depletion depth of the device at its maximum voltage. The minimum ion range as a function of rated VDS is given in the table below.

Table 3-18. Minimum Ion Range as a Function of Rated VDS

Max rated V_{DS} (V)	Minimum ion range (microseconds)
Up to 100	30
100 to 250	40
250 to 400	80
400 to 1000	200

STPS-421 The application shall be derated to 75% of the established survival voltage.

STPS-422 In the event that the application cannot be derated to 75% of the established survival voltage, a derating factor of 40% (of VDS rated) shall be applied for up to 200V devices from International Rectifier and Intersil when no data are available.

STPS-423 For any other device type and/or vender, a derating factor of 25% shall be applied when no data is available.

STPS-424 All power MOSFET may be susceptible to SEGR in the off mode, sensitivity shall be evaluated at the worst-case application.

STPS-425 The survival VDS voltage shall be established from exposure to minimum fluence of 1E6 ions/cm2 with a minimum LET of 26 LET MeVcm2/mg and a range that

is sufficient to penetrate the depletion depth of the device at its maximum voltage. The minimum ion range as a function of rated VDS is given in the table above.

STPS-426 The application shall be derated to 75% of the established survival voltage.

STPS-427 In the event that the application cannot be derated to 75% of the established survival voltage, a derating factor of 40% (of VDS rated) shall be applied for up to 200V devices from International Rectifier and Intersil when no data are available.

STPS-428 For any other device type and or vendor, a derating factor of 25% shall be applied when no data is available.

STPS-429 For single particle events like SEU, SET, and MBU, the criticality of a part in its specific application shall be defined. Please refer to the Single Event Effect Criticality Analysis (SEECA) document (431-REF-000273) for details. A SEECA analysis or a Failure Modes Effects Analysis (FMEA) should be performed at the system level.

STPS-430 Component heavy-ion and proton testing (and from these a rate calculation) shall be performed on each application of each part.

STPS-431 SEE testing and analysis shall take place based on LETth of the candidate parts as described in the table below.

Table 3-19. Environment to be Assessed Based on SEE part LET Threshold

Part Threshold	Environment to be Assessed
LET_{th} < 12 MeVcm^2/mg	Galactic Cosmic Rays, Solar Events Heavy ions and protons
LET_{th} = 12-75 MeVcm^2/mg (destructive events) LETth = 12-37 MeVcm^2/mg (non destructive events)	Galactic Cosmic Ray Heavy Ions, Solar Events Heavy Ions
LET_{th} > 75 MeVcm^2/mg (destructive events) LETth > 37 MeVcm^2/mg (non destructive events)	No analysis required

SEE environment specification (recall top level shielding is 100 mils equivalent Al):

STPS-432 For non-destructive events, a radiation design margin of 2 shall be used on all environment estimates when considering their effects on component performance.

STPS-433 The cosmic ray integral-flux LET spectrum to be used for analysis shall be per Figure 3-10 and Table A8 of the Lunar Reconnaissance Orbiter Radiation Environment Specification (431-SPEC-000020).

STPS-434 The solar particle event integral-flux LET spectrum to be used for analysis shall be per Figure 3-11 and Table A9 of the Lunar Reconnaissance Orbiter Radiation Environment Specification (431-SPEC-000020).

STPS-435 The worst-case solar proton energy spectra to be used for analysis shall be per Figure 3-12 and Table A10 of the Lunar Reconnaissance Orbiter Radiation Environment Specification (431-SPEC-000020).

STPS-436 The improper operation caused by single particle events like SEU, SET and MBU shall be reduced to acceptable levels.

STPS-437 Systems engineering analysis of circuit design, operating modes, duty cycle, device criticality, etc. shall be performed to determine acceptable levels for that device. Means of gaining acceptable levels include part selection, error detection and correction schemes, redundancy and voting methods, error tolerant coding, or acceptance of errors in non-critical areas.

3.6 MECHANICAL REQUIREMENTS

This section defines the limit loads, mechanical environments, and mechanical verification requirements of the LRO spacecraft components. All loads and environments in this document are preliminary and will be updated as the LRO spacecraft is defined.

3.6.1 Definitions

Qualification Test: A test performed on non-flight hardware. The purpose of the test is to prove that a new design meets one or more of its design requirements. Qualification testing is performed at maximum expected flight levels plus a margin. Test durations are typically longer than for acceptance tests.

Protoflight Test: A test performed on flight hardware. The purpose of the test is to prove that a new design meets one or more of its design requirements. Protoflight testing is performed at maximum expected flight levels plus a margin. Test durations are typically the same as for acceptance tests.

Acceptance Test: A test performed on flight hardware. The purpose of this test is to prove that a particular flight unit has been manufactured properly. The design has already been proven during a qualification or protoflight test program. Acceptance testing is performed at maximum expected flight levels.

3.6.2 Environments

3.6.2.1 Launch Limit Loads

STPS-438 The component shall demonstrate its ability to meet its performance requirements after being subjected to the net CG limit loads shown in the table below. Linear interpolation should be used between breakpoints to determine the appropriate limit load as a function of component weight. Note that these design limit loads are intended to only cover the low frequency launch environment and must be used in conjunction with the random vibration environments to assess structural margins.

Table 3-20. Component Limit Loads

Component Mass (kg)	Limit Load (g, any direction)
0.5 or less	35.9
2	33.6
5	30.1
10	26.8
15	24.5
20	22.8
30	19.9
50	17
60	16
70	15
80	14.4
100.0 or Greater	13.4

3.6.2.2 On-Orbit Limit Loads

STPS-439 The component shall meet its performance requirements while being subjected to 0.1 g loads during on-orbit operations.

3.6.2.3 Sinusoidal Vibration

STPS-440 The Contractor shall demonstrate by test up to 50 Hz and by analysis from 50 to 100 Hz the component's ability to meet its performance requirements after being subjected to the following sine vibration environment. These levels are to be applied at the LRO/component interface.

Table 3-21. Instrument Sine Vibration Environment

Frequency	Protoflight/Qual Level	Acceptance Level
5 - 100 Hz	8 g's	6.4 g's

Levels may be notched to not exceed 1.25 times the design limit load. These levels will be updated as coupled-loads analysis (CLA) data becomes available.

3.6.2.4 Acoustics

STPS-441 The component shall be designed to meet its performance requirements after being subjected to the acoustic environment listed in the table below. The sound pressure levels are based on the specified launch vehicles only. The acoustic environment for other fairing configurations may differ and need to be evaluated. Please note that the Atlas V sound pressure levels were increased to satisfy the General Environmental Verification Standards (GEVS) for Flight Programs and Projects (GSFC-STD-7000) minimum workmanship environment.

Table 3-22. Limit Level Acoustic Environments

Center Frequency (Hz)	Limit Level Sound Pressure Level (dB)
25	114.0
31.5	119.5
40	125.1
50	125.2
63	126.3
80	128.0
100	129.0
125	130.0
160	130.0
200	130.0
250	130.0
315	130.0
400	129.5
500	128.0
630	125.0
800	123.0
1000	121.0
1250	119.5
1600	118.0
2000	116.5
2500	115.0
3150	113.5

Center Frequency (Hz)	Limit Level Sound Pressure Level (dB)
4000	112.0
5000	114.0
6300	113.5
8000	114.0
10000	115.0
OASPL	140.1

3.6.2.5 Random Vibration

STPS-442 The Contractor shall demonstrate by random vibration analysis along with static loads analysis the component's ability to meet its performance requirements after being subjected to the following random vibration environment. These levels are to be applied at the LRO/component interface.

Table 3-23. Component Random Vibration Environment

Frequency (Hz)	Protoflight/Qual Level	Acceptance Level
20	0.026 g^2/Hz	0.013 g^2/Hz
20 – 50	+6 dB/Octave	+6 dB/Octave
50 – 800	0.160 g^2/Hz	0.080 g^2/Hz
800 – 2000	-6 dB/Octave	-6 dB/Octave
2000	0.026 g^2/Hz	0.013 g^2/Hz
Over All	14.1 grms	10.0 grms

The above random environment is appropriate for components weighing 22.7 kg (50 pounds [lbs]) or less. This environment will be updated with random vibration analysis. Note for lightweight components, the highest design loads may be from this random vibration environment. Please see NASA-HDBK-7005 and NASA-STD-7001 for more information.

3.6.2.6 Shock

STPS-443 The maximum expected shock environment at the component interface shall be as shown in the table below. This shock environment will be updated.

STPS-444 The component shall be assessed for damage due to shock based on shock sensitivity or proximity to shock sources. If the component is not considered susceptible to the shock environment, shock testing can be deferred to the level of assembly that allows for actuation of the actual shock-producing device.
If the component is considered to be susceptible to the shock environment, the contractor may need to perform a shock test to demonstrate that the item can

survive the predicted shock environment. The LRO Project will assess shock environment based on the specific component location.

Table 3-24. Limit Level Shock Response Spectrum

Frequency (Hz)	Level (Q=10)
100 100 to 1000 1000 to 10000	150 g +9.2 dB/Octave 5000 g

3.6.2.7 Venting

STPS-445 If the component has less than 0.25 square inches of vent area for each cubic foot volume, it shall demonstrate the ability to survive the maximum pressure profiles described in the figures below. Please see the Delta IV Payload Planners Guide and the Atlas Launch System Mission Planner's Guide for more information.

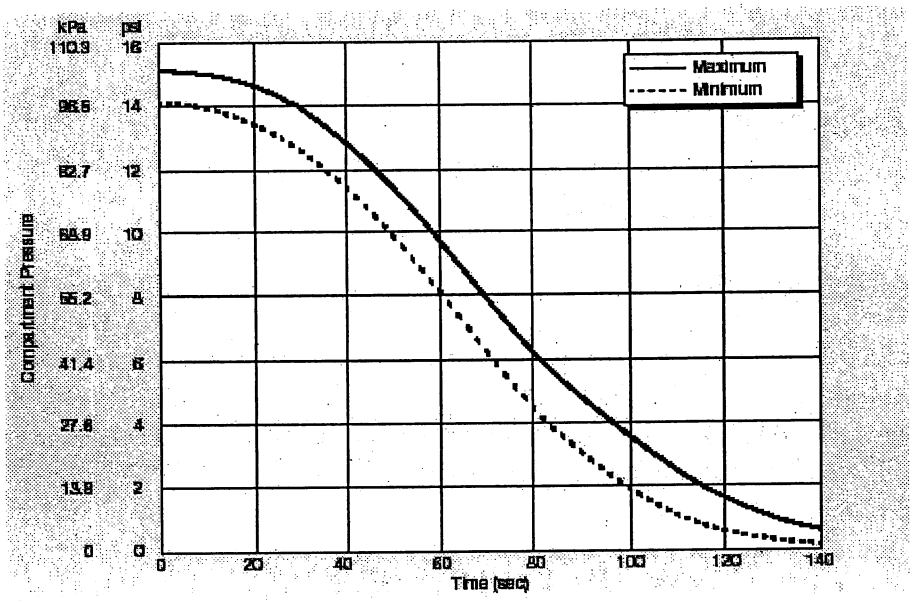


Figure 3-11. Delta IV Payload Fairing Compartment Absolute Pressure Envelope

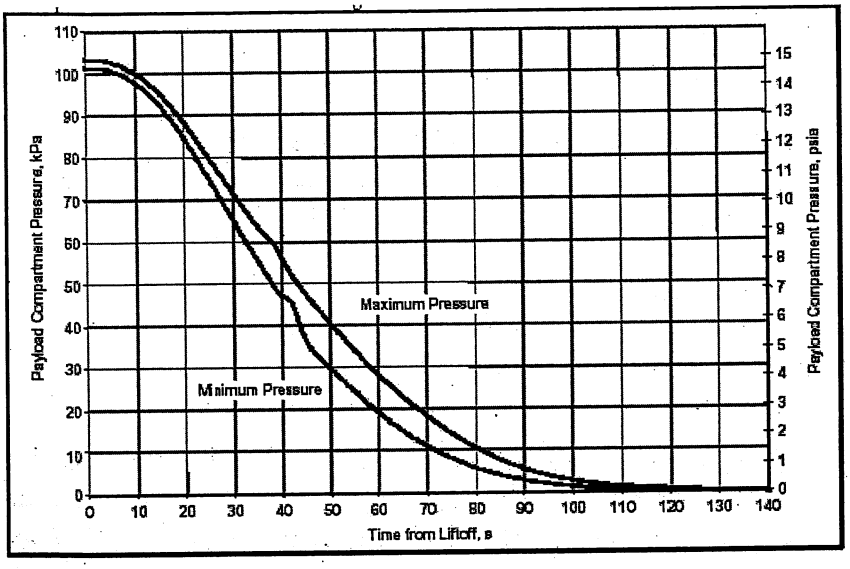


Figure 3-12. Atlas V Typical Static Pressure Profiles Inside the Payload Fairing

3.6.3 Frequency Requirement

STPS-446 The component shall have a fundamental frequency greater than 50 Hz when hard mounted at its spacecraft interface.

3.6.4 Verification Requirements

3.6.4.1 Factors of Safety

STPS-447 The component as well as mechanical GSE (MGSE) shall demonstrate positive Margins of Safety for all yield and ultimate failures using the Factors of Safety (FS) defined in the table below (see NASA-STD-5001 for more information on other materials [e.g. glass]).

Table 3-25. Factors of Safety

Type of Hardware	Design Factor of Safety	
	Yield	Ultimate
Tested Flight Structure – metallic	1.25	1.4
Tested Flight Structure – beryllium	1.4	1.6
Tested Flight Structure - composite*	N/A	1.5
Pressure Loaded Structure	1.25	1.5
Pressure Lines and Fittings	1.25	4.0
Untested Flight Structure - metallic only	2.0	2.6

Type of Hardware	Design Factor of Safety	
	Yield	Ultimate
Ground Support Equipment	3.0	5.0
Transportation Dolly/Shipping Container	2.0	3.0

*All composite structures must be tested to 1.25 x limit loads
Margin of Safety (MS) is defined as follows:
MS = (Allowable Stress(or Load)/(Applied Limit Stress(or Load) x FS)) -1

3.6.4.2 Test Factors

STPS-448 The following test factors and durations, shown in the following table, shall be used for prototype, protoflight, and flight hardware. The hardware definitions are included in the General Environmental Verification Specification (GEVS) for GSFC Flight Programs and Projects (GSFC-STD-7000).

Table 3-26. Test Factors and Durations

Test	Qualification	Protoflight	Acceptance
Structural Loads Level Duration Centrifuge Sine Burst[1]	 1.25 X Limit Load 1 Minute 5 Cycles Full Level	 1.25 X Limit Load 30 Seconds 5 Cycles Full Level	 Limit Load[2] 30 Seconds 5 Cycles Full Level
Acoustic Level Duration	 Limit Level +3dB 2 Minutes	 Limit Level +3dB 1 Minute	 Limit Level 1 Minute
Random Vibration Level Duration	 Limit Level +3dB 2 Minutes/Axis	 Limit Level +3dB 1 Minute/Axis	 Limit Level 1 Minute/Axis
Sine Vibration Level Sweep Rate[3]	 1.25 X Limit Level 2 Octaves/Minute/Axis	 1.25 X Limit Level 4 Octaves/Minute/Axis	 Limit Level 4 Octaves/Minute/Axis
Shock Actual Device Simulated	 2 Actuations 1.4 X Limit Level 2 Actuations/Axis	 2 Actuations 1.4 X Limit Level 1 Actuations/Axis	 1 Actuation Limit Level 1 Actuation/Axis

(1) Sine burst testing shall be done a frequency sufficiently below primary resonance as to ensure rigid body motion.
(2) All composite structures must be tested to 1.25 x limit loads. All beryllium structures must be tested to 1.4 x limit loads.
(3) Unless otherwise specified these sine sweep rates shall apply.

3.6.4.3 Frequency Verification Requirements

STPS-449 the contractor shall perform a frequency verification test, such as a low level sine sweep.

STPS-450 Frequencies shall be verified and reported up to 200 Hz.

3.6.5 Finite Element Model Requirements

STPS-451 If the component has a predicted first frequency below 75 Hz, the contractor shall provide Finite Element Models (FEMs) for LRO structural analysis. These FEMs have the following requirements.

3.6.5.1 Finite Element Model Documentation

STPS-452 Each formal finite element model submittal shall be submitted with documentation that describes the following:

- The version of the model.
- A list of element, node, property, and material identification (ID) numbers.
- A description of the nonstructural mass represented on each property card.
- A description of units.
- A description of the local reference coordinate system.
- The results of validity checks.
- Mass Properties (CG location, Inertias, and total model mass).
- Frequencies of the first ten modes while in a free-free boundary condition.

3.6.5.2 Finite Element Model Submittal

STPS-453 Formal finite element model submittals shall adhere to the following:

- Model submitted as a MacNeal Schwendler Corporation (MSC)/ NASA Structural Analysis (NASTRAN) data deck.
- Model file name includes the date (YYMMDD) that they were made at the beginning of their name.
- All model property and material cards have descriptive names.
- Models submission is "full" model with no symmetry assumptions made to reduce model size.
- Model includes no "Super Elements".
- Model submission includes an explicit Single Point Constraint set.
- Until actual hardware mass properties are verified and final, the finite element model is adjusted to the maximum allocated mass for each subsystem and component.
- Model passes the following validity checks: unit enforced displacement and rotation, free-free dynamics with equilibrium check, and unit gravity loading.

- Finite element models used for thermal analysis pass a unit increased temperature check.

3.7 THERMAL REQUIREMENTS

3.7.1 Flight Interface Design Temperature Limits

All temperatures refer to the temperature of the component's mounting surface.

STPS-454 The component shall meet all performance requirements over the flight operational temperature limits of -10 to +50 °C.

STPS-455 The component qualification shall demonstrate that the component meets all performance requirements over the temperature limits of -20 to +60 °C.

STPS-456 The component shall survive exposure to the survival temperature limits of -20 to +60 °C.

STPS-457 The component shall demonstrate turn on at the cold survival limit of -20 °C.

3.7.2 Ground Test Environment

STPS-458 The component shall be able to operate in a lab environment with air temperature between 15 and 25 °C and relative humidity between 35 and 70%.

STPS-459 The component shall survive without degradation transportation temperatures of 15 to 30 °C and relative humidity of 0 to 70%.

3.7.3 Allocation of Spacecraft Monitored Temperature Sensors

STPS-460 The component shall provide temperature sensors as defined in Section 3.2.2.5.8.1.

3.7.4 Model Documentation

STPS-461 The Reduced Geometric Math Models (RGMMs) and Reduced Thermal Math Models (RTMMs) delivered to GSFC shall be accompanied by appropriate model documentation as specified in the Lunar Reconnaissance Orbiter S-Band Telemetry, Tracking and Command Subsystem Statement of Work (431-SOW-000303).

3.7.5 Component Thermal Test Documentation

STPS-462 The final thermal qualification test plan shall be approved by the LRO Thermal Systems Lead.

STPS-463 Target temperatures and overall test setup shall be discussed with the LRO Thermal Systems Lead.

3.8 LIFE REQUIREMENTS

3.8.1 Mission Life

STPS-464 The component shall meet all performance specifications throughout 1 year of ground testing and 14 months of operation in space.

3.8.2 Shelf Life

STPS-465 The component shall not suffer any degradation in performance when stored for ten years when packaged using agreed-to procedures

4.0 VERIFICATION REQUIREMENTS

The contractor shall conduct a verification program that demonstrates the hardware design is qualified and meets all requirements contained in this document. The contractor shall provide a verification matrix defining the method of verification for each specific requirement of this document. Verification methods include inspection, analysis, test or a combination of these techniques.

4.1 INSPECTION

Verification by inspection includes visual inspection of the physical hardware, a physical measurement of a property of the hardware, or the documentation search demonstrating hardware of an identical design has demonstrated fulfillment of a requirement.

4.1.1 Visual Inspection

Visual inspection of the physical hardware by a customer appointed qualified inspector.

4.1.2 Physical Measurement

Physical measurement of hardware property (i.e. mass, dimensions, etc.) demonstrating the hardware meets specific requirement.

4.1.3 Documentation Search

Verification of requirements based on similarity shall include supporting rationale and documentation and shall be approved by the GSFC COTR

4.2 ANALYSIS

Verification of performance or function through detailed analysis, using all applicable tools and techniques, is acceptable with GSFC COTR approval.

4.3 TEST

Represents a detailed test of performance and/or functionality throughout a properly configured test setup where all critical data taken during the test period is captured for review.

Performance parameter measurements shall be taken to establish a baseline that can be used to assure that there are no data trends established in successive tests that indicate a degradation of performance trend within specification limits that could result in unacceptable performance in flight.

4.4 TEST RESTRICTIONS

4.4.1 Failure During Tests

The test shall be stopped if equipment fails during testing in cases where this failure will result in damage to the equipment. Otherwise, the test shall be completed to obtain as much information as possible. No replacement, adjustment, maintenance, or repairs are authorized during testing. This requirement does not prevent the replacement or adjustment of equipment that has exceeded its design operating life during tests, provided that after such replacement, the equipment is tested as is necessary to assure its proper operation.

A complete record of any exceptions taken to this requirement shall be included in the test report.

4.4.2 Modification of Hardware

Once the formal acceptance test has started, cleaning, adjustment, or modification of test hardware shall not be permitted.

4.4.3 Re-Test Requirements

If any event, including test failure, requires that a component be disassembled and reassembled, then all tests performed prior to the event must be considered for repeat. If the unit has multiple copies of the same build, then all units must be examined to determine if the problem is common. If all copies require disassembly for repair, then each must receive the same test sequence.

4.5 REQUIRED VERIFICATION METHODS

The following measurements, tests, environments, and inspections are required for each component to provide assurance that the component meets specified performance, functional, environmental, and design requirements. Each test or demonstration is described below.

a. Weight and Envelope Measurements
b. Initial Alignment (if necessary), Performance and Functional Tests
c. EMI/EMC Tests
d. Shock Test (if necessary)
e. Loads Test (Prototype/Protoflight only)
f. Sine Vibration
g. Random Vibration
h. Thermal Vacuum
i. Final Alignment (if necessary), Performance and Functional Tests

4.5.1 Weight and Envelope Measurement

Measurement of the weight and envelope of the component shall be made to show compliance with specified requirements and provide accurate data for the mass properties control program.

4.5.2 Performance Tests

The component shall be tested to demonstrate compliance with performance requirements, including alignment if necessary. Performance Tests are detailed functional tests conducted under conditions of varying internal and external parameters with emphasis on all possible modes of operation for the component.

A Performance Test shall be conducted at the beginning and end of each acceptance test.

Functional Tests are abbreviated Performance Tests done periodically during or following the component environmental testing in order to show that changes or degradation to the component have not resulted from environmental exposure, handling, transporting, or faulty installation.

4.5.3 EMI/EMC

The tests described in the EMI/EMC requirements section shall be performed on each flight unit. It is encouraged to perform these EMI tests as early as possible in the development. All tests shall be performed with the component in its most sensitive mode for susceptibility testing and in its most noisy mode as appropriate for the EMI emission test

4.5.4 Loads Verification

Structural design loads shall be applied to prototype or protoflight hardware. There is no requirement to strength test flight hardware that has already been strength tested through a prototype or protoflight program (ie, there is no "acceptance level" strength test requirement for flight hardware).

Structural Loads testing can be verified by performing either a fixed frequency Sine Burst test, a series of static loads pull tests, or, if approved, analysis.

No permanent deformation may occur as a result of the loads test, and all applicable alignment requirements must be met following the test. Units that require alignment will have an alignment check following loads testing. A performance test will be conducted to verify that no damage occurred due to the loads test.

The component shall be powered during static loads tests.

4.5.4.1 Sine Burst

A simple Sine Burst test following the random vibration test in each axis is a convenient method to conduct a structural loads test. This test applies a ramped sine input at a sufficiently low frequency such that the test item moves as a rigid body. An analysis is required to show that a base drive Sine Burst test will not cause over-test or under-test in some areas of the structure. Duration: 5 cycles of full level amplitude.

4.5.4.2 Static Pull

Static pull tests are another method to perform loads testing and can be applied at flight interfaces in a static test facility. The loads can be applied either as component loads applied simultaneously, or the single resultant vector load can be applied to the test point. Strain gages are generally positioned around the test point to verify deflection predictions from the analytical model.
Test Duration: 30 seconds

4.5.4.3 Analysis

If appropriate development tests are performed to verify accuracy of the stress model, stringent quality control procedures are invoked to ensure conformance of the structure (materials, fasteners, welds, processes, etc.) to the design, and the structure has well-defined load paths, then strength qualification may be accomplished by a stress analysis that demonstrates that the hardware has positive margins on yield at loads equal to 2.0 times the limit load, and positive margins on ultimate at loads equal to 2.6 times the limit load. Such alternative approaches shall be reviewed and approved on a case-by-case basis. Please contact the LRO Project to seek approval.

4.5.5 Random Vibration

The component shall be subjected to a random vibration test along each axis to the appropriate levels and durations shown in the mechanical requirements section.

The test item shall be mounted to the test fixture as it would be mounted to the spacecraft.

A functional test shall be performed before the start of testing and after a test in each axis.

Prior to the test, a survey of the test fixture/exciter combination will be performed to evaluate the fixture dynamics and the proposed choice of control accelerometers.

The component shall be powered during test.

4.5.6 Sine Vibration

The component shall be subjected to swept sine vibration testing to the appropriate levels and durations shown in the mechanical requirements section.

Components which are powered on at launch shall meet this requirement when powered. (Note: The S-Band TT&C Subsystem is powered on during launch and ascent phases)

4.5.7 Sine Sweep

The Signature Sine sweep shall be conducted on each component before and after vibration testing in each axis. This test is a tool to verify no change in structural integrity from testing and to verify the primary resonant frequency.

4.5.8 Thermal Vacuum Test

The component shall be cycled a total of eight (8) times at the component level. During these tests, chamber pressure shall be less than 1.33 X 10-3 Pa. (1 X 10-5 torr). Thermal cycling will be to full qualification limits.

Components shall be in flight configuration. However, in cases that do not involve mechanisms, thermal blankets may be omitted to speed the transition times between temperature extremes. If thermal blankets are omitted, and test blankets are not used, a concurrence from the LRO Thermal Systems Lead is required.

4.5.8.1 Chamber Pump-Down

During the pump-down, power and RF line voltages will be monitored to demonstrate the absence of corona discharge and multipaction. Only those items powered during launch will be powered for this test.

4.5.8.2 Temperature Transitions

Transitions from cold to hot conditions increase contamination hazards because material that has accreted on the chamber walls may evaporate and deposit on the relatively cool test item. Transitions will be conducted at rates sufficiently slow to prevent that from occurring.

Testing shall start with a hot soak and end with a hot soak to minimize this risk.

If the component is sensitive to orbit transience, its performance shall be monitored during hot to cold transitions at a rate that a flight like orbit average case might experience.

4.5.8.3 Hot/Cold Turn-On Demonstration

Components or subsystems shall be turned on twice after exposure to hot and cold survival temperatures (see Figure 4-1 below).

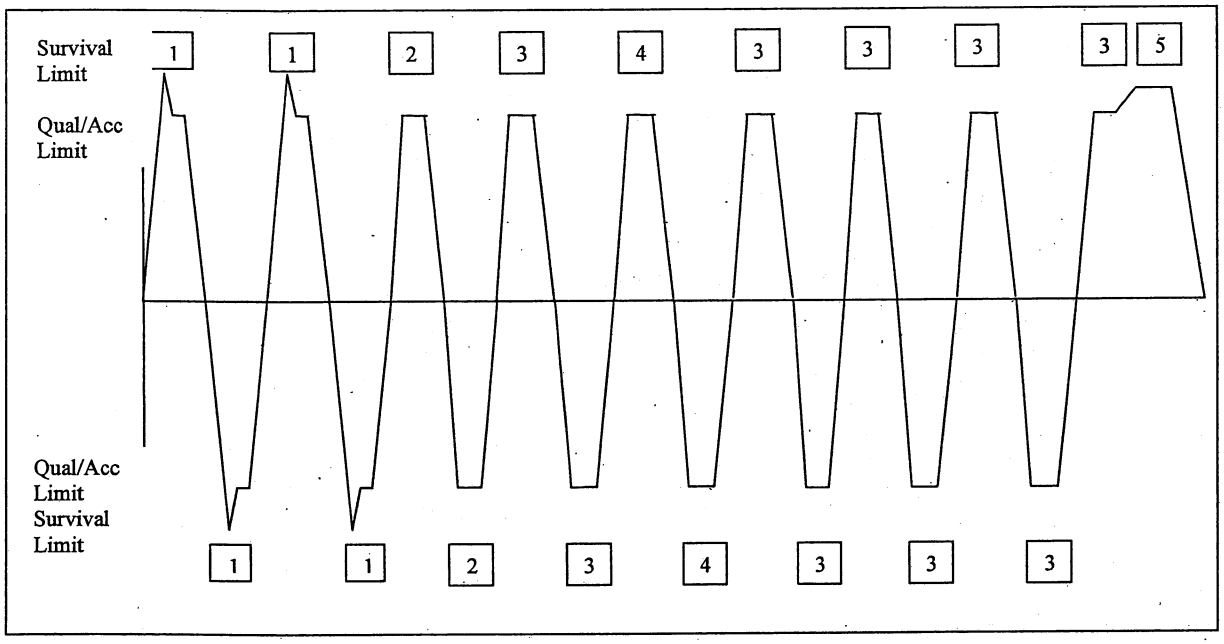


Figure 4-1. Thermal Vacuum Profile

1= Achieve survival temp, stabilize 1 hour, return to qualification temperature, turn on, soak at test temperature 4 hours, run performance test.
2 = Soak at test temperature 4 hours, run performance test voltage = 21V
3 = Soak at test temperature 4 hours, run performance test voltage = 28V
4 = Soak at test temperature 4 hours, run performance test voltage = 35V
5 = Bakeout phase

4.5.8.4 Electrical System Performance

The electrical system and performance will also be verified for minimum, maximum, and nominal voltages at minimum and maximum temperatures and during temperature transitions.

Maximum Bus Voltage:	35V
Nominal Bus Voltage:	28V
Minimum Bus Voltage:	21V

Functional tests or performance tests will be conducted during the hot and cold soaks. Immediately following the component thermal vacuum cycling will be the bakeout phase to eliminate volatiles. See Figure 4-1 above.

First 2 cycles (all units)

During the transition from cold to warm, switch component OFF, increase temperature to upper survival temp for 1 hour, then return to upper qualification temperature, verify that component

turns ON, and verify nominal performance once the component has reached the qualification temperature. Begin hot soak.

During the transition from warm to cold, switch component OFF, decrease temperature to lower survival temp for 1 hour, then return to lower qualification temperature, verify that component turns ON, and verify nominal performance once the component has warmed to the qualification temperature. Begin cold soak.

Soak time at each temperature: 4 hours, run Performance Test during soak.

Number of complete cycles:

Prototype Unit:	8 full cycles, start and end on hot cycle. Include min, max and nominal bus voltages. Use Qualification temperatures per Section 3.7.1 as the "test temperature."
Protoflight Unit:	8 full cycles, start and end on hot cycle. Include min, max and nominal bus voltages. Use Qualification temperatures per Section 3.7.1 as the "test temperature."
Flight / Copy / Spare Unit:	8 full cycles, start and end on hot cycle. Include min, max and nominal bus voltages. Use Acceptance temperatures per Section 3.7.1 as the "test temperature."

4.5.8.5 Bakeout

The components shall be baked-out prior to delivery to GSFC.

The bake-out performance shall be measured using a temperature-controlled Quartz Crystal Microbalance (TQCM) at chamber pressures below 10E-5 torr. The bake-out shall be performed at the hardware's maximum hardware survival temperature, unpowered, for 48 hours followed by a 12 hour period, powered, at the maximum operational temperature as defined in Section 3.7.1.

The TQCM shall be maintained at -40 °C throughout the test to measure total outgassing of volatile outgassed condensables without the influence of water vapor. The TQCM must have a representative view of the hardware, preferably a vent.

The following test data shall be collected and delivered to GSFC: Chamber configuration (i.e., chamber size, use of shrouds, TQCM location, cold finger/scavenger plate locations (if used), and general test setup), TQCM readings (taken as a minimum every 0.5 hours), hardware temperature, chamber/shroud temperature, TQCM temperature, and pressure.

Appendix A. Abbreviations and Acronyms

Abbreviation/ Acronym	DEFINITION
AGC	Automatic Gain Control
ARC	Ambiguity Resolution Code
BPSK	Binary Phase Shift Keyed
BRF	Band-Reject Filter
C&DH	Command and Data Handling
CCSDS	Consultative Committee on Space Data System
CMD	Command
dB	Decibel
dBm	Decibel relative to one milliwatt
DPE	Dynamic phase error
FEC	Forward Error Correction
GEVS	General Environmental Verification Specification
HGA	High Gain Antenna
I&T	Integration and Test
IF	Intermediate Frequency
LGA	Low Gain Antenna
LRO	Lunar Reconnaissance Orbiter
NASA	National Aeronautics and Space Administration
NRZ-L	Non-Return-to-Zero, Logic level coding
NRZ-M	Non-Return-to-Zero, Manchester coding
NTIA	National Telecommunication and Information Administration
PPL	Phase Locked Loop
PPM	Parts per million
RF	Radio Frequency
RMS	Root Mean Squared
STDN	Spaceflight Tracking and Data Network
SNR	Signal to Noise ratio
TCXO	Temperature Compensated Crystal Oscillator
TLM	Telemetry
TT&C	Telemetry, Tracking and Command
UART	Universal Asynchronous Receiver / Transmitter
USB	Unified S-Band
VCXO	Voltage Controlled Crystal Oscillator
VSWR	Voltage Standing Wave Ratio

431-LIST-000304
Revision -

Lunar Reconnaissance Orbiter Project

S-Band Telemetry, Tracking and Command Subsystem Deliverable Items List and Schedule

February 8, 2006

Goddard Space Flight Center
Greenbelt, Maryland

National Aeronautics and Space Administration

TABLE OF CONTENTS

1.0 INTRODUCTION

This document is the Lunar Reconnaissance Orbiter (LRO) S-Band Telemetry, Tracking and Command (TT&C) Subsystem Deliverable Items List and Schedule (DILS). This document provides specific information on the hardware and data deliverables for the S-Band TT&C Subsystem.

1.1 PROPRIETARY DATA

Some of the content of documents may be of a proprietary nature to the document preparing/ sending Party. In the event data is deemed to be proprietary, and for which protection is to be maintained, the sending Party shall mark the document with a notice to indicate that the data therein is proprietary and shall be used and disclosed by the receiving Party and its related entities (e.g., contractors and subcontractors) only for the purposes of fulfilling the receiving Party's responsibilities under the LRO Project, and that the identified and marked technical data shall not be disclosed or retransferred to any other entity without prior written permission of the document preparer.

1.2 APPLICABLE DOCUMENTS

431-SOW-000303	Lunar Reconnaissance Orbiter S-Band Telemetry, Tracking and Command Subsystem Statement of Work
431-SPEC-000121	Lunar Reconnaissance Orbiter S-Band Telemetry, Tracking and Command Subsystem Performance Specification
EEE-INST-002	Instructions for EEE Parts Selection, Screening, Qualification, and De-rating

2.0 DELIVERABLE DOCUMENTATION

This section provides a tabular listing of documentation deliverables, including the following information:

Description: This provides the Title of the deliverable item.

Reference: This provides the reference back to the pertinent document calling out the deliverable.

Category:

A = Approval: Documents in this category require approval from the National Aeronautics and Space Administration (NASA)/Goddard Space Flight Center (GSFC) Contracting Officer (CO). In general, documents shall be provided in contractor format as long as required content, as specified in the Lunar Reconnaissance Orbiter S-Band Telemetry, Tracking and Command Subsystem Statement of Work (431-SOW-000303), is addressed. The NASA/GSFC CO reserves the time-limited right of disapproval for each submission. The time-limited period is two weeks from receipt of documents.

R= Review: Documents in this category do not require formal NASA/GSFC CO approval. They must be received within a specified time period and are subject to evaluation.

I = Information: Documents in this category are informal and are for information only.

Quantity: This provides the required number of copies for the deliverable. All data is required to be submitted electronically. The number in the quantity column refers to the number of hard copies required.

Delivery Date: This provides the fixed or relative date or time that the deliverable is required.

2.1 DATA DELIVERY DOCUMENTATION AND SCHEDULE

Item #	Description	Reference	Category	Quantity	Delivery Date
1	Monthly Status Report (MSR)	SOW Section 3.1	I	1	Ten (10) calendar days following the month being reported.
2	Preliminary Design Review (PDR)	SOW Section 3.3.1	R	1	Three (3) months after Award of Contract
3	Preliminary Design Review Report	SOW Section 3.3.1	A	1	Ten (10) calendar days after completion of PDR
4	Critical Design Review (CDR)	SOW Section 3.3.2	R	1	Three (3) months after PDR
5	Critical Design Review Report	SOW Section 3.3.2	A	1	Ten (10) calendar days after completion of Critical Design Review (CDR)
6	Pre-Environmental Review (PER)	SOW Section 3.3.3	A	1	Five (5) calendar days before start of environmental testing on Qualified Unit
7	Flight Unit Pre-Shipment Review (PSR)	SOW Sect 3.3.4	A	1	Five (5) calendar days prior to delivery of each Qualification and Flight Unit
8	Preliminary Interface Control Document (ICD)	SOW Sect 4.2.1	A	3	Fifteen (15) calendar days before PDR
9	Draft Interface Control Document (ICD)	SOW Sect 4.2.1	R	1	30 calendar days after contract award
10	ICD (Final)	SOW Sect 4.2.1	A	3	Fifteen (15) calendar days before CDR
11	Preliminary Drawing Package	SOW Sect 4.2.2	R	3	Fifteen (15) calendar days before PDR
12	Drawing Package (Final)	SOW Sect 4.2.2	A	3	Fifteen (15) calendar days before CDR
13	Preliminary Design Review Presentation Package	SOW Sect 4.2.3	I	5	Fifteen (15) calendar before PDR
14	Critical Design Review Presentation Package	SOW Sect 4.2.4	I	5	Fifteen (15) calendar before CDR
15	Flight Unit Data Delivery Package	SOW Sect 4.2.5	A	1	With each delivered Transponder
16	Preliminary Verification Test Plan	SOW Sect 4.2.6	R	3	Fifteen (15) calendar days before PDR
17	Verification Test Plan (Final)	SOW Sect 4.2.6	A	3	Fifteen (15) calendar days before CDR

Item #	Description	Reference	Category	Quantity	Delivery Date
18	Verification Test Procedures	SOW Sect 4.2.7	A	3	Thirty (30) calendar days before start of testing and as changes occur.
19	Preliminary Thermal Analysis	SOW Sect 4.3	R	2	Fifteen (15) calendar days before PDR
20	Thermal Analysis (Final)	SOW Sect 4.3	A	2	Fifteen (15) calendar days before CDR
21	Preliminary Reduced Thermal Model	SOW Sec. 4.3.1	R	2	Fifteen (15) calendar days before PDR
22	Final Reduced Thermal Model	SOW Sect. 4.3.1	A	2	Fifteen (15) calendar days before CDR
23	Final Detailed Thermal Model	SOW Sect. 4.3.1	A	2	Fifteen (15) calendar days before CDR
24	Preliminary Structural Analysis	SOW Sect 4.4	R	2	Fifteen (15) calendar days before PDR
25	Structural Analysis (Final)	SOW Sect 4.4	A	2	Fifteen (15) calendar days before CDR
26	Quality Assurance Plan	SOW Sect 6.1.1	A	3	Twenty-eight (28) calendar days after contract award
27	Class I Configuration Management (CM) Changes	SOW Sect 6.1.3	A	2	Five (5) calendar days after Contractor CM review
28	Class II CM Changes	SOW Sect 6.1.3	R	2	Five (5) calendar days after Contractor CM review
29	Anomaly Reports	SOW Sect 6.1.4	A	2	Five (5) calendar days after Contractor Anomaly Review Process determines disposition
30	Preliminary Flight Unit Failure Mode and Effects Analyses (FMEA)	SOW Sect 6.3.1	R	2	Fifteen (15) calendar days before PDR
31	Final Flight Unit Failure Mode and Effects Analyses (FMEA)	SOW Sect 6.3.1	A	2	Fifteen (15) calendar days before CDR
32	Parts Stress Analysis Criteria if different from EEE-INST-002	SOW Sect 6.3.2	A	2	Twenty-eight (28) calendar days after contract award
33	Preliminary Parts Stress Analysis	SOW Sect 6.3.2	R	2	Ten (10) calendar days before PDR
34	Parts Stress Analysis (Final)	SOW Sect 6.3.2	A	2	Ten (10) calendar days before CDR
35	Worst-Case Circuit Analysis (Preliminary)	SOW Sect 6.3.3	R	2	Fifteen (15) calendar days before PDR
36	Worst-Case Circuit Analysis (Final)	SOW Sect 6.3.3	A	2	Fifteen (15) calendar days before CDR

Item #	Description	Reference	Category	Quantity	Delivery Date
37	Preliminary Reliability Prediction	SOW Sect. 6.3.4	I	2	Fifteen (15) calendar days before PDR
38	Reliability Prediction (Final)	SOW Sect. 6.3.4	A	2	Fifteen (15) calendar days before CDR
39	Trend Parameter List	SOW Sect 6.5.2	R	3	Five (5) calendar days prior to PER
40	Test and Trend Analysis Reports	SOW Sect 6.5.2	I	1	Delivered at PSR
41	Printed Wiring Board (PWB) Coupons	SOW Sect 6.6.5.1	A	1 Coupon per board	Deliver Twenty-one (21) calendar days before start of PWB assembly
42	Advanced Packaging Technology Requirements Documentation	SOW Sect 6.6.5.3	A	2	Twenty-eight (28) calendar days after contract award
43	Parts Identification List (Preliminary)	SOW Sect 6.7.1	R	5	Fifteen (15) calendar days before PDR
44	Parts Identification List (Final)	SOW Sect 6.7.1	A	5	Fifteen (15) calendar days before CDR
45	Documentation on Custom Devices	SOW Sect 6.7.2	A	2	Twenty-eight (28) calendar days after contract award
46	Plastic Encapsulated Microcircuit (PEM) Specification Documents	SOW Sect 6.7.3	A	2	Twenty-eight (28) calendar days after contract award
47	Radiation Test Plans (If Applicable)	SOW Sect 6.7.4	R	2	Plans submitted thirty (30) calendar days prior to test. Returned with comments within fifteen (15) calendar days.
48	Radiation Test Reports	SOW Sect 6.7.4	A	2	Ten (10) calendar days after test
49	Recertification Plans for Parts >5Yrs (If Applicable)	SOW Sect 6.7.5	A	2	Fifteen (15) calendar days before CDR
50	As-Built Parts List	SOW Sect 4.2.5	R	1	Due at PSR
51	Alert/Advisory Disposition and Preparation	SOW Sect 6.7.6	R	2	Due 3 working days after Contractor disposition
52	Preliminary Materials Identification List	SOW Sect 6.8.1	A	5	Fifteen (15) calendar days before PDR
53	Materials Identification List (Final)	SOW Sect 6.8.1	A	5	Fifteen (15) calendar days before CDR
54	As-Built Materials List	SOW Sect 6.8.1	R	1	Due at Five (5) calendar days prior to PSR
55	Preliminary Materials Usage Agreement	SOW Sect 6.8.2	R	2	Fifteen (15) calendar days before PDR

Item #	Description	Reference	Category	Quantity	Delivery Date
56	Materials Usage Agreement (Final)	SOW Sect 6.8.2	A	2	Fifteen (15) calendar days before CDR
57	Limited-Life Items List	SOW Sect 6.3.4	A	2	Fifteen (15) calendar days before PDR
58	Close Out Photos	SOW Sect. 4.2.5	R	1	Due at PSR

Appendix A. Abbreviations and Acronyms

Abbreviation/ Acronym	DEFINITION
CCB	Configuration Control Board
CCR	Configuration Change Request
CDR	Critical Design Review
CM	Configuration Management
CMO	Configuration Management Office
CO	Contracting Officer
DILS	Deliverable Items List and Schedule
EEE	Electrical, Electronic, and Electromechanical
ESD	Electro Static Discharge
FMEA	Failure Mode and Effect Analyses
GSFC	Goddard Space Flight Center
INST	Instrument
LRO	Lunar Reconnaissance Orbiter
MSR	Monthly Status Review
NASA	National Aeronautics and Space Administration
PDR	Preliminary Design Review
PEM	Plastic Encapsulated Microcircuit
PER	Pre-Environmental Review
PSR	Pre-Shipment Review
PWB	Printed Wiring Board
SOW	Statement of Work
SPEC	Specification
TBD	To be Determined
TBR	To be Reviewed/Resolved

MEMORANDUM OF AGREEMENT REGARDING MASTER SUBCONTRACTING PLAN

Contractor:

General Dynamics C4 Systems (C4S)
8201 E. McDowell Road
Scottsdale, AZ 85257-3812

General Dynamics Network Systems (NS)
77 A Street
Needham, MA 02194

General Dynamics Advanced Information Systems (AIS)
1421 Jefferson Davis Highway
Arlington, VA 22202

This Master Subcontracting Plan will be used by General Dynamics C4S, NS and AIS in the performance of contracts with the United States Government which incorporate this plan, in implementing the provisions thereof applicable to Small Businesses, and Small Businesses owned and controlled by socially and economically disadvantaged subcontractors, including HUBZone Small Businesses, Woman-Owned Small Businesses, Veteran-Owned Small Businesses and Service Disabled Veteran-Owned Small Businesses.

Period Covered by Agreement: **October 1, 2004 through December 31, 2007**

Approved By the Contracting Officer

Signature: _____ **Date:** 11/17/04

James Galligan
Divisional Administrative Contracting Officer (DACO)

NOTE: This Plan is approved by the Defense Contract Management Agency ACO for GDC4S. The Procuring Contracting Officer (PCO) is responsible for approving specific goals under the individual subcontracting plan (Exhibit B) submitted for each awarded contract.

Prepared By:

Signature: _____ **Date:** 10/28/04

Robert Kane, Director
Supply Chain Management and Small Business Liaison Officer

General Dynamics Advanced Information Systems, C4 Systems and Network Systems
400 John Quincy Adams Road
Taunton, MA 02780-1069
Email: robert.kane@gdc4s.com
Phone: (508) 880-4829
Fax: (508) 880-2223

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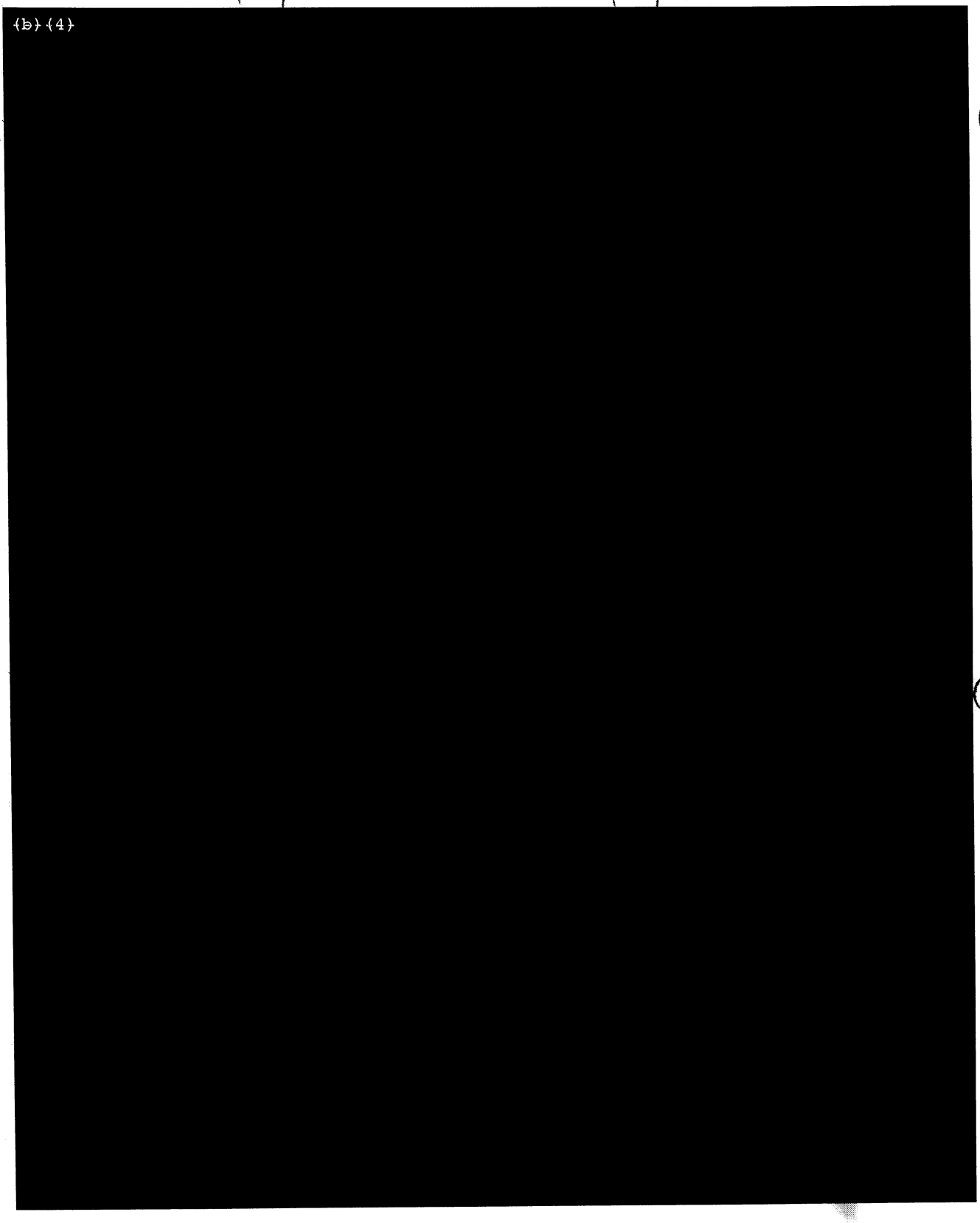

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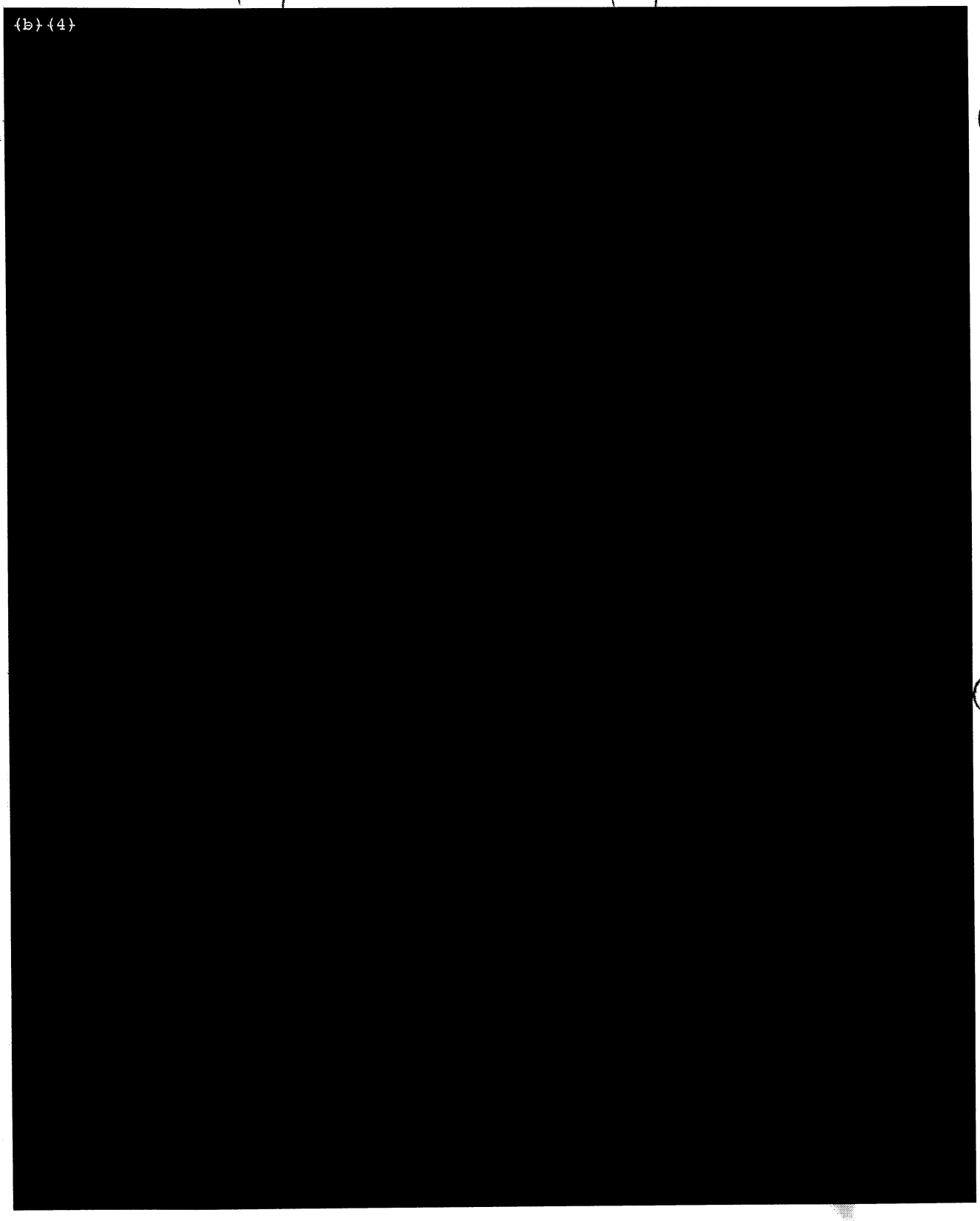

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Robert Kane, Director
Supply Chain Management and Small Business Liaison Officer

General Dynamics Advanced Information Systems, C4 Systems and Network Systems
400 John Quincy Adams Road
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Email: robert.kane@gdc4s.com
Phone: (508) 880-4829
Fax: (508) 880-2223

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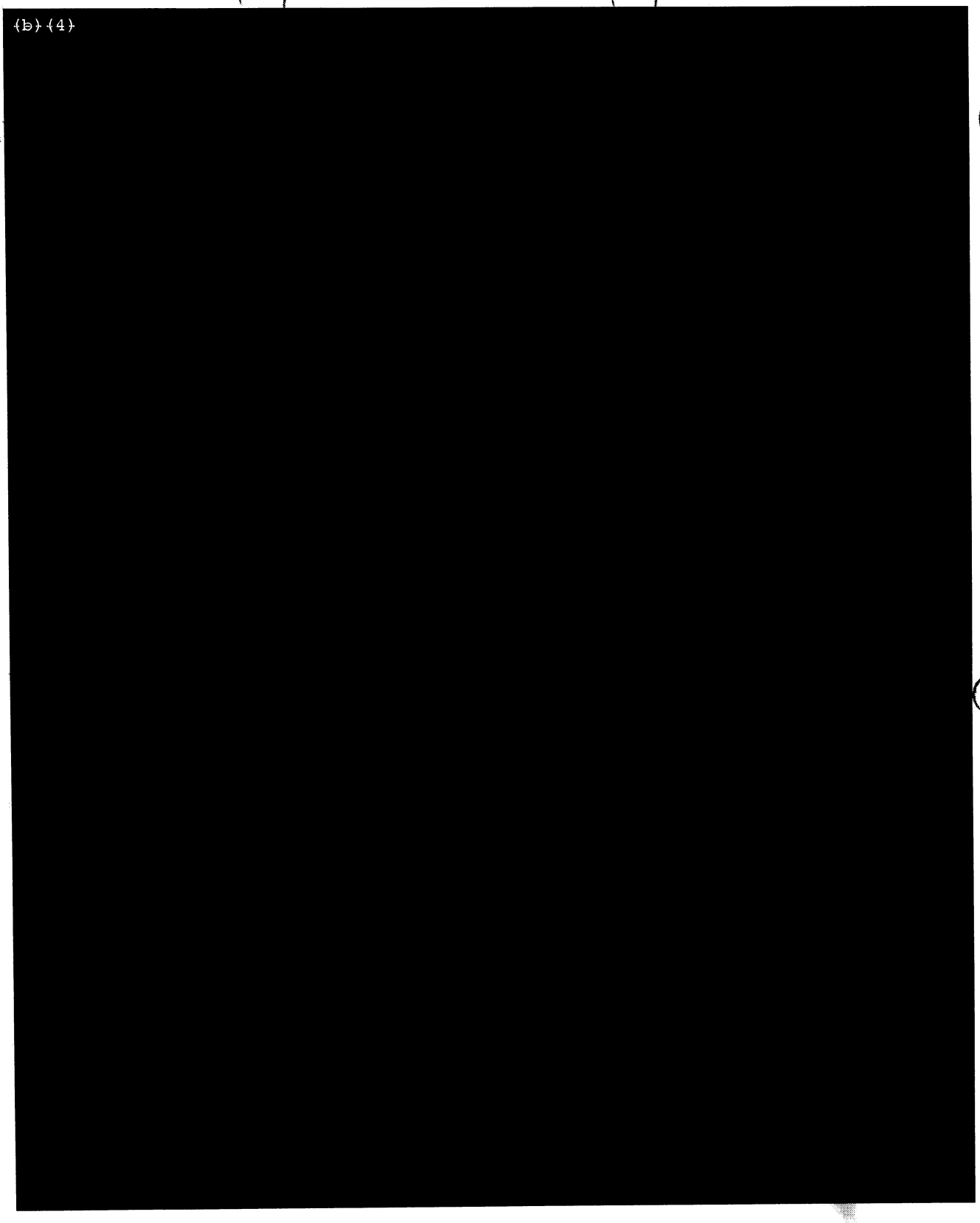

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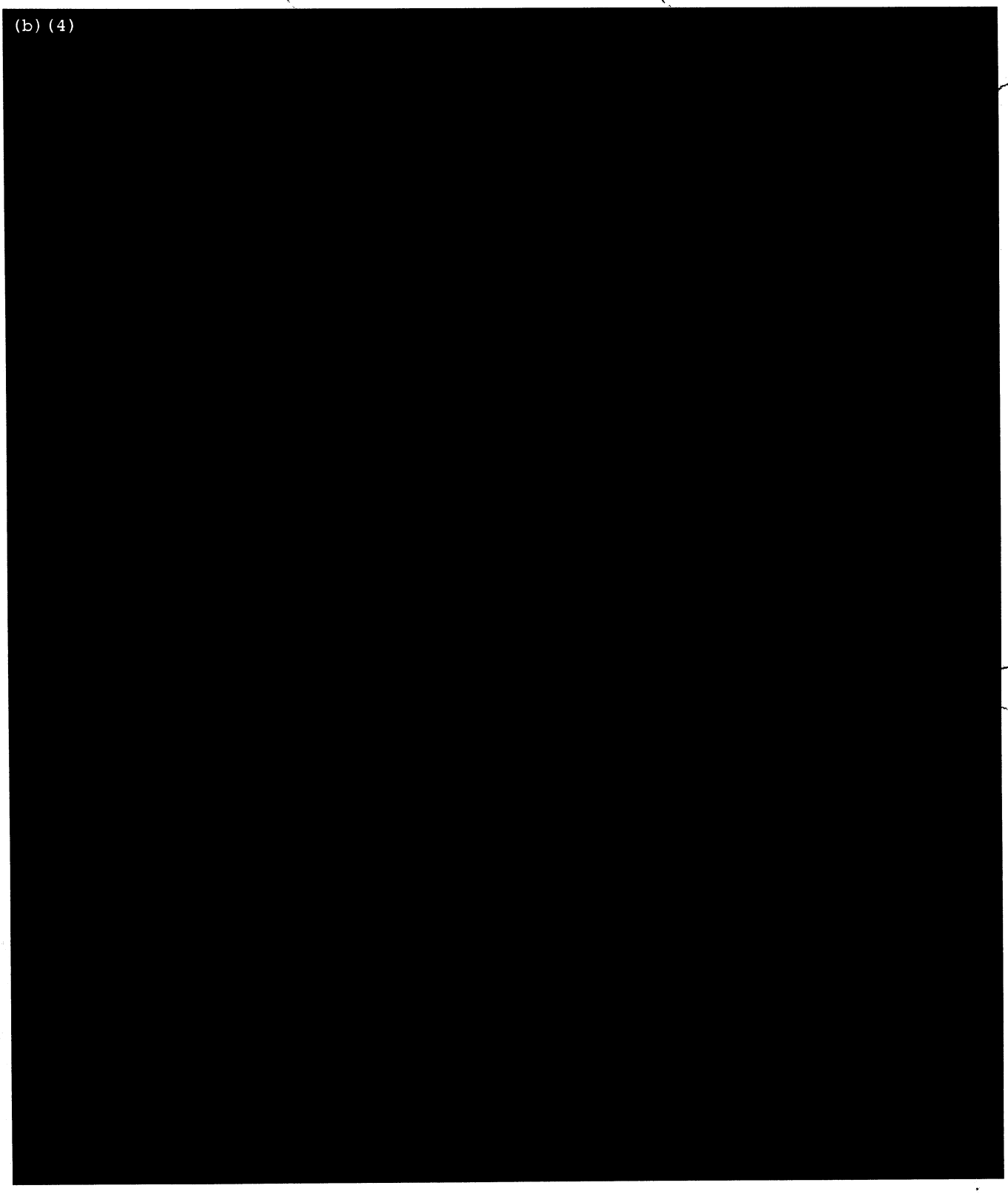

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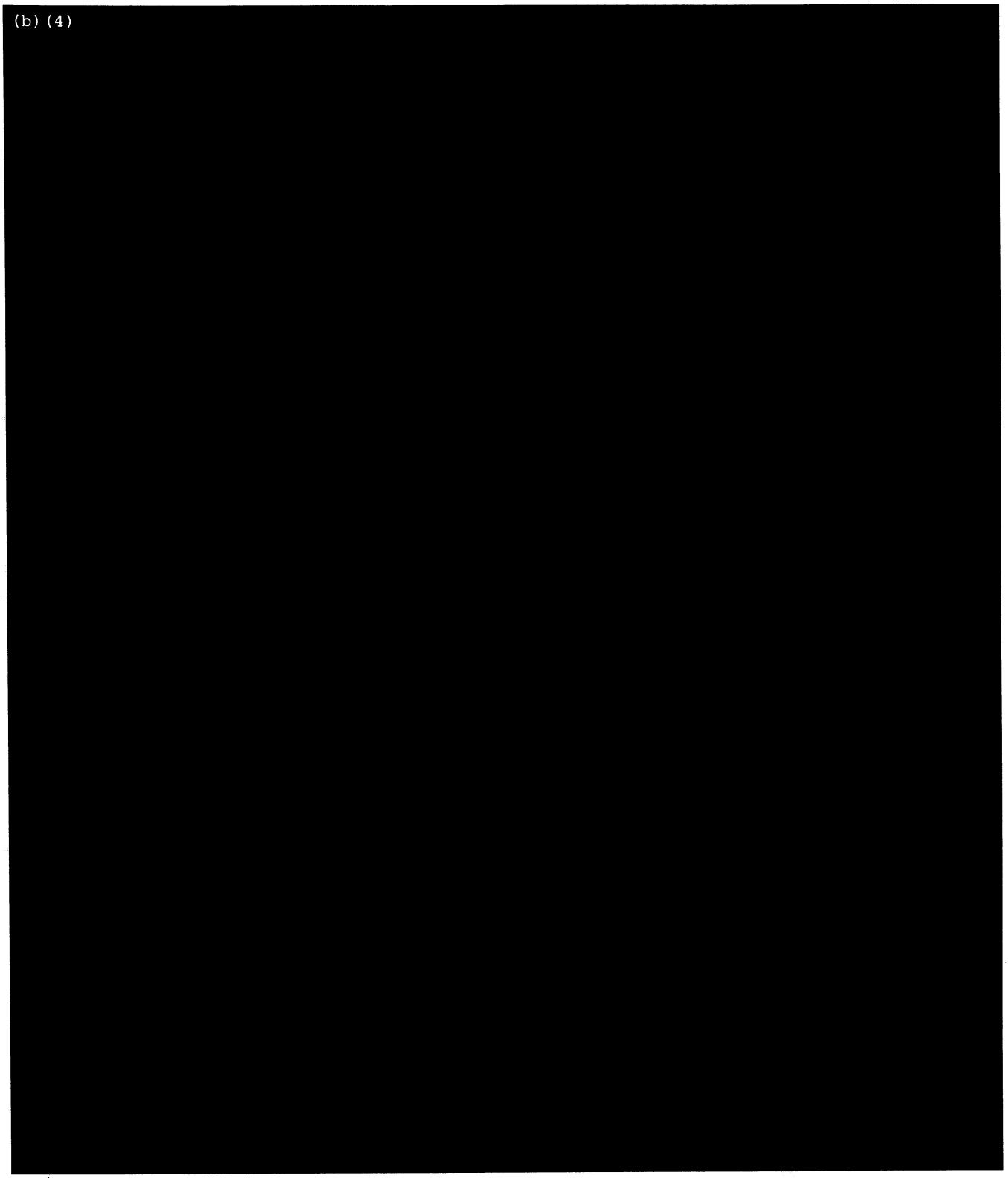

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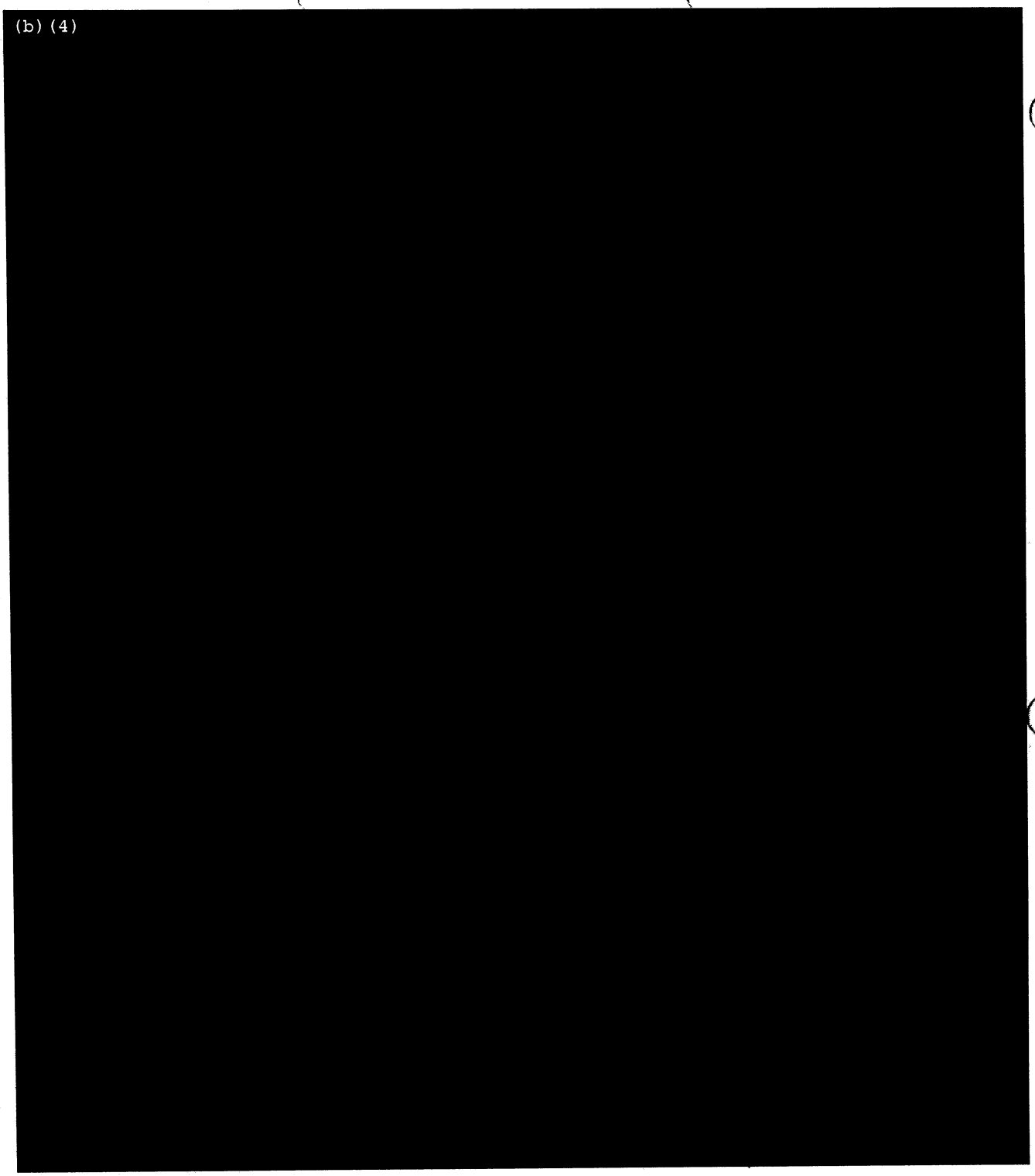

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EXHIBIT A

General Dynamics C4 Systems Facilities Locations

Arlington, VA
1919 South Eads Street, Suite 400
Arlington, VA 22202

Calgary, Alberta, Canada
1020 68th Avenue N.E.
Calgary, Alberta, Canada T2E 8P2

Chantilly, VA
14900 Conference Center Drive
Suite 200
Chantilly, Virginia 20151

Columbia, MD
8955 Guilford Road
Suite 200
Columbia, MD 21046

Fort Wayne, IN
1025 Goshen Avenue
Fort Wayne, IN 46808-2060

Huntsville, AL
6000 Technology Drive
Building 6
Huntsville, Alabama 35805

Killeen, TX
5011 FM 2410
Killeen, TX 76543

Lexington, MA
430 Bedford Street
Suite 150
Lexington, MA 02173

Linthicum, MD
1306 Concourse Drive, Suite 310
Linthicum, MD 21090-1027

1190 Winterson Road
Suite 350
Linthicum, MD 21090

Needham, MA
77 "A" Street
Needham, MA 02494

Orlando, FL
12424 Research Parkway
Suite 217
Orlando, FL 32826

Ottawa, Ontario, Canada
3785 Richmond Road
Ottawa, Ontario, Canada K2H 5B7

***Scottsdale, AZ**
8220 E. Roosevelt St.
Scottsdale, AZ 85257

8201 E. McDowell Road
Scottsdale, AZ 85252

Taunton, MA
400 John Quincy Adams Road, Bldg. 80
Taunton, MA 02780

** The Scottsdale, AZ addresses are the former Decision Systems business unit that will merge with C4 Systems effective 1/1/05.*

EXHIBIT A

General Dynamics Network Systems Facilities Locations

Arlington, VA
1000 Wilson Blvd., Suite 810
Arlington, VA 22209

Baltimore, MD
International Telecom Group USA
1920 Frankfurst Avenue
Baltimore, MD 21226

Chantilly, VA
15000 Conference Center Drive
Chantilly, VA 20151-3819

Chesapeake, VA
700 Independence Parkway, Suite 150
Chesapeake, VA 23320

Dallas, TX Site
1875 Walnut Hill Lane, Suite 110
Irving, TX 75038

El Segundo, CA
898 Sepulveda Blvd.
El Segundo, CA 90245-3457

Needham, MA
77 A Street
Needham, MA 02194-2892

Oklahoma City, OK
3600 S. MacArthur, Suite B
Oklahoma City, OK 73179

Rome Italy
Page Europe Spa
Via Simone Martini n° 127/129

EXHIBIT A

General Dynamics Advanced Information Systems Facilities Locations

Arlington, VA (Jefferson Plaza 2) Headquarters
1421 Jefferson Davis Highway, Suite 600
Arlington. VA 22202-3028

1400 Key Boulevard, Suite 700
Arlington, VA 22209

Anaheim Hills, CA
180 North Riverview Drive
Suite 300
Anaheim Hills, CA 92808

Ann Arbor, MI
1200 Joe Hall Drive
Ypsilanti, MI 48197

Annapolis Junction, MD
National Business Park
2721 Technology Drive, Suite 400
Annapolis Junction, MD 20701

Arlington/Rosslyn, VA
1000 Wilson Blvd., Suite 810 - Upper Mall
Arlington, VA 22209

Beavercreek, OH
2673 Commons Blvd., Suite 200
Beavercreek, OH 45431

Bloomington, MN
8800 Queen Avenue South
Bloomington, MN 55431

Buffalo, NY
4455 Genessee Street
Buffalo, NY 14225

Chantilly, VA
14700 Lee Road
Chantilly, VA 20151

Colorado Springs, CO
1450 Academy Park Loop
Colorado Springs, CO 80910

Dayton, OH
2700 Indian Ripple Road
Dayton, OH 45440-3638

Englewood, CO
8005 S. Chester Street, Suite 325
Englewood, CO 80112-3538

Fairfax, VA
10560 Arrowhead Dr
Fairfax, VA 22030

Fairfax, VA
12450 Fair Lakes Circle, Suite 800Fairfax, VA
22033

Florham Park, NJ
7-9 Vreeland RoadFlorham Park,
NJ 07932

Greensboro, NC
3801 Boren DriveGreensboro,
NC 7407-2046

McLeansville, NC
5440 Millstream Road
McLeansville, NC 27301

Hampton, VA
2101 Executive Drive
Hampton, VA 23666

Herndon, VA
19250 Worldgate Drive, Suite 300
Herndon, CA 20170

Mountain View, CA
100 Ferguson Drive, P.O. Box 7188
Mountain View, CA 94039-7188

Orlando, FL
12506 Lake Underhill Road, Bldg E-9
Orlando, FL 32825

Pittsfield, MA
100 Plastics Avenue
Pittsfield, MA 01201

Reston, VA
1840 Michael Faraday Drive, Suite 230
Reston, VA 20190

Rome, NY
Beeches Technical Campus
Route 26 North, Bldg. 4, Suite 2
Rome, NY 13440

San Antonio, TX
145 Duncan Drive, Suite 300
San Antonio, TX 78226

Suffolk, VA
7025 Harbour View Blvd., Suite 101
Suffolk, VA 23435

EXHIBIT B – PROGRAM SPECIFIC GOALS

MP6021
Rev: -

PROGRAM NAME: LRO Program
PROPOSAL #: 66060-1000
DATE: 3/31/06

The goals for utilization of Small Business, Small Disadvantaged Business, Small Woman-Owned Business, HUBZone Business Concerns, Service-Disabled Veteran-Owned Small Business and Veteran-Owned Small Business as defined in FAR 52.219-9 are:

Total Proposed Costs: Current submission

Purchase Material :	$750,000
Major Sub dollars :	$0
Total subcontract dollars expected:	$750,000

Type:

Original	Update	Contract Mod
X		

SBLO Stephanie Poppe
480-441-7255 stephanie.poppe@gdds.com

1. **Large Business:**
Large Business concerns will be awarded 67.90% of the total cost of direct material.
This represents $509,250 of the proposed cost.

The principal product areas to be subcontracted to large business concerns in this plan are as follows:

(b) (4)

2. **Total Dollars/Percentages for Small Business Concerns:** (This includes Small Business, Small Disadvantaged Business, Small Woman-Owned Business, HUBZone Business Concerns, Service-Disabled Veteran-Owned Small Business and Veteran-Owned Small Business dollars/percentages.)

Total percentage: 32.100%
Total Small Business dollars: $240,750
(Items A - F below may exceed the total value of item 2.)

A. Small Business (Non-Disadvantaged):
Small Business concerns will be awarded 27.850% of the total cost of direct material.
This represents $208,875 of the proposed cost.

The principal product areas to be subcontracted to small business concerns in this plan are as follows:

(b) (4)

B. Small Woman-Owned Business:
Small Woman-Owned Business concerns will be awarded 5.620% of the total cost of direct material.
This represents $42,150 of the proposed cost.

The principal product areas to be subcontracted to small woman-owned business concerns in this plan are as follows:

(b) (4)

EXHIBIT B – PROGRAM SPECIFIC GOALS

MP6021
Rev: -

PROGRAM NAME: LRO Program
PROPOSAL: 66060-1000
DATE: 3/31/06

C. Small Disadvantaged Business:

Small Disadvantaged Business concerns will be awarded 4.250% of the total cost of direct material.
This represents $31,875 of the proposed cost.

The principal product areas to be subcontracted to small disadvantaged business concerns in this plan are as follows:

(b) (4)

D. HBCU'S (Historically Black Colleges & Universities)/MI's (Minority Institutions):

HBCU's will be awarded 0.000% of the total cost of direct material.
This represents $0 of the proposed cost.

The principal product areas to be subcontracted to HBCU/MI concerns in this plan are as follows:

E. HUBZone Business:

HUBZone Business concerns will be awarded 1.000% of the total cost of direct material.
This represents $7,500 of the proposed cost.

The principal product areas to be subcontracted to HUBZone business concerns in this plan are as follows:

(b) (4)

F. Veteran-Owned Small Business:

Veteran-Owned Small Business concerns will be awarded 9.89% of the total cost of direct material.
This represents $74,175 of the proposed cost.

The principal product areas to be subcontracted to Veteran-Owned Small Business concerns in this plan are as follows:

(b) (4)

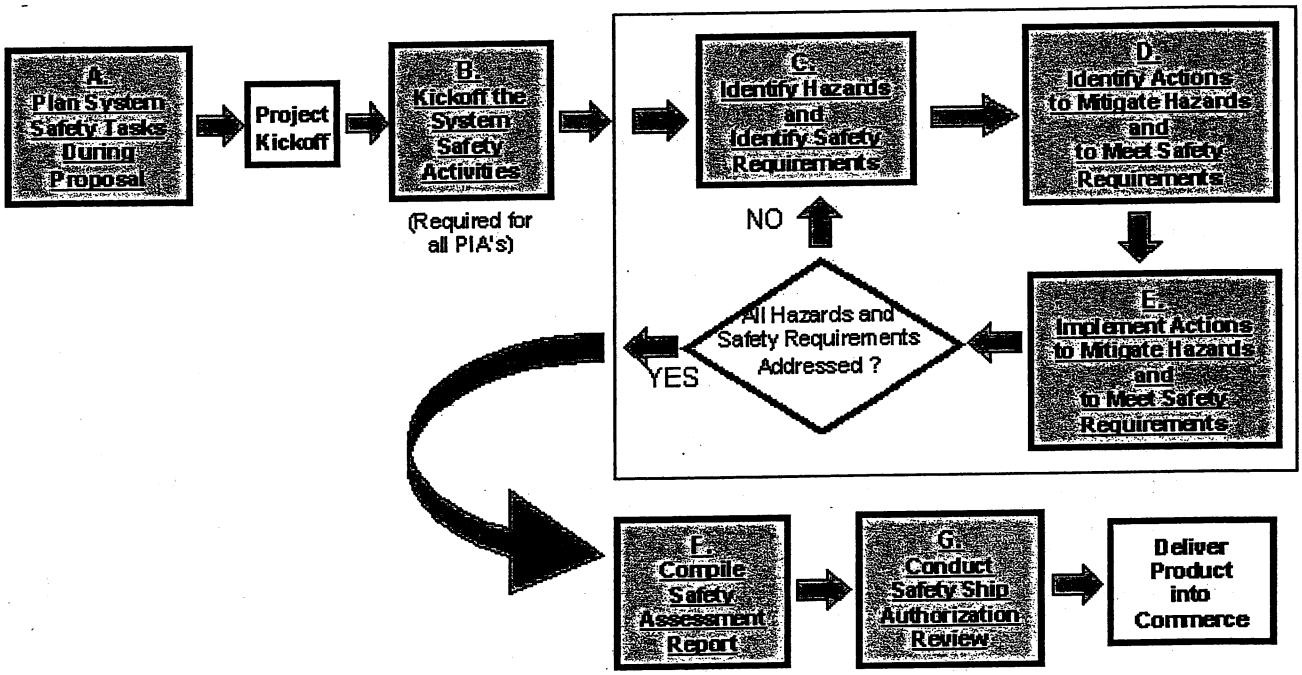
F.1. Service-Disabled Veteran-Owned Small Business:

Service-Disabled Veteran-Owned Small Business concerns will be awarded 0.00% of the total cost of direct material. This represents $0 of the proposed cost.

The principal product areas to be subcontracted to Service-Disabled Veteran-Owned Business concerns in this plan are as follows:

GENERAL DYNAMICS C4 SYSTEMS' HEALTH AND SAFETY REQUIREMENTS

General Dynamics C4 Systems West is a certified OSHA VPP[1] STAR[2] site, ISO 9000, ISO 14001 and OHSAS 18001 Registered site. The company's written Environmental Health and Safety policies, procedures, and standard practices ensure the safety and health of its employees and on-site visitors (including subcontractors and NASA personnel), and the safety of the working conditions. The company's Product Safety policies, procedures, and practices ensure that our customers are provided with products and services that are safe and compliant with applicable laws and regulations, industry accepted standards and related General Dynamics directives. The term "product" includes items (embedded or otherwise) developed by C4 Systems or its subcontractors, or otherwise provided by a supplier or furnished by an original equipment manufacturer for use in C4 Systems products including: hardware; software; systems, or integrated solutions, made up of any hardware or software items; equipment or tools; and services, installations or other furnished operational capabilities. The company's defined Product Safety process is shown in the following flow diagram. The 7 key steps (A through G) provide a thorough and repeatable methodology for ensuring that products are designed to be safe and compliant with applicable laws, regulations, accepted industry standards, and related company directives.



System Safety Process

[1] VPP - Voluntary Protection Participant
[2] STAR - Safety Through Accountability and Recognition (the top OSHA award)

These policies and procedures extend to any location where General Dynamics employees perform work for a program to ensure the protection of personnel, property, equipment, and the environment in the production of contractor products and or the pursuit of any of its activities. As part of this process, if a work site has a health and safety plan, the site's requirements will be integrated into General Dynamics' plan for that site.

The following is a list of the internal written Environmental Health and Safety policies, operating standards and instructions that support standard operations and certifications.

ENTERPRISE POLICIES AND PROCESSES

EXECUTIVE POLICIES

EP 3, Rev. B, "Environmental, Health and Safety (EHS)" dated 02/03/05

ENVIRONMENTAL, HEALTH AND SAFETY MANAGEMENT SYSTEM

OM 7.4.0, Rev. D, "Environmental, Health & Safety Management System Manual" dated 01/06/06

BP 7.4.0.1, Rev. –, "Environmental Aspects Process" dated 09/08/05

BP 7.4.0.2, Rev. –, "Occupational Health and Safety Risk Assessment Process" dated 09/06/05

OS 7.4.0.3, Rev. A, "EHS Legal Requirements" dated 02/02/06

OS 7.4.0.4, Rev. A, "EHS Objectives, Targets and Programs" dated 03/24/06

OS 7.4.0.5, Rev. A, "EHS Responsibility and Resources" dated 03/24/06

BP 7.4.0.6, Rev. A, "EHS Competence, Awareness and Training" dated 03/24/06

OS 7.4.0.7, Rev. A, "EHS Communication and Consultation" dated 03/24/06

OS 7.4.0.8, Rev. A, "EHS Document Control" dated 03/24/06

OS 7.4.0.9, Rev. A, "Operational Control Process" dated 03/24/06

OS 7.4.0.10, Rev. A, "EHS Purchasing Process" dated 03/24/06

OS 7.4.0.11, Rev. A, "Emergency Planning" dated 03/24/06

OS 7.4.0.12, Rev. A, "EHS Performance, Monitoring and Measurement" dated 03/24/06

OS 7.4.0.13, Rev. A, "EHS Compliance Evaluation" dated 03/24/06

OS 7.4.0.14, Rev. A, "EHS Non-conformance and Corrective and Preventive Action" dated 01/06/06

OS 7.4.0.15, Rev. –, "Control of Records" dated 09/27/05

OI 7.4.0.16, Rev. B, "EHS Internal Audit" dated 03/24/06

OS 7.4.0.17, Rev. A, "EHS Management Review" dated 03/24/06

OS 7.4.0.18, Rev. A, "EHS Monitoring and Measurement Equipment" dated 03/24/06

POLLUTION PREVENTION SYSTEMS

OI 7.4.1, Rev. D, "Pollution Prevention System" dated 12/16/05

OI 7.4.1.1, Rev. D, "Refrigerant Management Program" dated 01/03/06

OI 7.4.1.2, Rev. D, "Hazardous and Chemical Waste Management" dated 05/26/05

OM 7.4.1.3, Rev. B, "Scottsdale Waste Water Treatment Plant (WWTP) Operations Manual" dated 05/26/05

OI 7.4.1.4, Rev. B, "Chemical Container Management" dated 02/28/05

OI 7.4.1.5, Rev. C, "PCB Plan" dated 08/22/05

OI 7.4.1.6, Rev. A, "Dust Control Program" dated 12/16/05

OI 7.4.1.7, Rev. D, "Storm Water Management Program" dated 11/15/05

OI 7.4.1.8, Rev. –, "Environmental Management Plan for Landscape and Pest Control Chemical" dated 09/07/04

HAZARDOUS MATERIALS MANAGEMENT SYSTEMS

OS 7.4.2, Rev. –, "Hazardous Material Management System" dated 08/01/03

OS 7.4.2.1, Rev. C, "Hazard Communication Program" dated 03/15/06

OS 7.4.2.2, Rev. D, "Control of Regulated Materials" dated 04/06/05

EMERGENCY PREPAREDNESS AND RESPONSE SYSTEMS

OM 7.4.3.1, Rev. H, "General Dynamics, Scottsdale, Arizona Facility – Emergency Action Plan" dated 01/06/06

OI 7.4.3.2, Rev. B, "General Dynamics Fire Department" dated 04/29/05

OS 7.4.3.3, Rev. A, "Fire Prevention Plan" dated 04/01/05

OI 7.4.3.4, Rev. A, "Automatic External Defibrillator (AED)" dated 03/29/05

OM 7.4.3.5, Rev. B, "First Aid Guidelines for Security Officers" dated 04/07/05

OS 7.4.3.6, Rev. A, "Emergency Equipment" dated 07/11/05

OS 7.4.3.7, Rev. A, "Emergency Preparedness - Non-Scottsdale Facilities" dated 04/01/05

OCCUPATIONAL HEALTH SYSTEMS

OI 7.4.4, Rev. C, "Occupational Health System" dated 12/02/05

OM 7.4.4.1, Rev. D, "Occupational Exposure to Chemical Contaminants" dated 05/27/05

OM 7.4.4.2, Rev. C, "Toxic Substances Control Act (TSCA) Plan" dated 06/01/05

OS 7.4.4.3, Rev. D, "Ionizing Radiation" dated 03/20/06

BP 7.4.4.4, Rev. D, "RF Energy Management" dated 02/16/06

OS 7.4.4.5, Rev. C, "Hearing Conservation Program" dated 02/16/06

OS 7.4.4.6, Rev. C, "Soldering Activities" dated 03/07/06

OI 7.4.4.7, Rev. C, "Asbestos Control Program" dated 06/01/05

OM 7.4.4.8, Rev. D, "General Dynamics, Scottsdale, Arizona Facility – Asbestos Operations and Maintenance Plan" dated 06/22/05

OI 7.4.4.9, Rev. C, "Laboratory Safety" dated 03/22/05

OS 7.4.4.10, Rev. D, "Laser Safety" dated 03/20/06

OS 7.4.4.11, Rev. B, "Drinking Water Program" dated 06/24/05

OS 7.4.4.12, Rev. B, "Bloodborne Pathogen Exposure Control Plan" dated 03/29/05

OI 7.4.4.13, Rev. C, "Program Participants Identification System" dated 02/16/06

OI 7.4.4.14, Rev. A, "Medical Records Release" dated 05/26/05

OI 7.4.4.15, Rev. D, "Medical Leave of Absence/Family Medical Leave Act" dated 05/26/05

OM 7.4.4.16, Rev. B, "Medical Directives Manual" dated 04/07/05

BP 7.4.4.17, Rev. B, "Medical Leave of Absence/Family Medical Leave Act" dated 05/26/05

OI 7.4.4.20, Rev. –, "Department of Transportation CDL Medical Clearance" dated 08/01/03

OI 7.4.4.21, Rev. –, "General Dynamics Fire Department a.k.a. Emergency Response Team" dated 08/01/03

OI 7.4.4.22, Rev. C, "Medical Monitoring Program" dated 07/07/05

OS 7.4.4.28, Rev. D, "Thermal Hazards" dated 02/16/06

OI 7.4.4.29, Rev. B, "Fermilab ODH Mathematical Model Application" dated 02/16/06

INJURY AND ILLNESS SYSTEMS

OI 7.4.5, Rev. A, "Injury and Illness System" dated 02/24/04

OI 7.4.5.1, Rev. D, "Accident/Incident Reporting and Investigation" dated 03/07/06

OI 7.4.5.2, Rev. A, "Injury Data Collection and Record Maintenance" dated 03/29/05

PERSONAL SAFETY SYSTEMS

OI 7.4.6, Rev. D, "Personal Safety System" dated 03/17/06

OS 7.4.6.1, Rev. C, "Lone Worker Rule" dated 02/16/06

OI 7.4.6.2, Rev. C, "Office/Production Area Housekeeping, Walking/Working Surfaces and Appliance Safety" dated 12/14/05

BP 7.4.6.3, Rev. G, "C4 Systems Ergonomics Program" dated 03/24/06

OM 7.4.6.4, Rev. E, "C4 Systems Ergonomic Coordinator's Kit" dated 02/16/06

OM 7.4.6.6, Rev. D, "Respiratory Protection Program" dated 03/20/06

OS 7.4.6.7, Rev. C, "Confined Space" dated 03/07/06

OS 7.4.6.8, Rev. D, "Personal Protective Equipment" dated 03/17/06

OS 7.4.6.9, Rev. D, "Fall Protection, Scaffolding and Roof Access" dated 03/09/06

OI 7.4.6.10, Rev. A, "Push Lock Wall Anchor System, Roof Top Single Anchor Points and Horizontal Cable System Instructions" dated 10/30/03

OS 7.4.6.11, Rev. F, "Electrical Safety and Lockout/Tagout" dated 03/17/06

OI 7.4.6.12, Rev. B, "Job Safety Analysis" dated 05/26/05

OM 7.4.6.15, Rev. A, "C4 Systems West Safety System (Our Voluntary Protection Program)" dated 03/31/05

EQUIPMENT SAFETY SYSTEMS

OI 7.4.7, Rev. C, "Equipment Safety System" dated 12/09/05

BP 7.4.7.1, Rev. B, "Hazardous Work Permit" dated 05/27/05

BP 7.4.7.2, Rev. D, "Equipment Installation, Relocation and Decommissioning" dated 03/09/06

OS 7.4.7.4, Rev. C, "Portable Powered Tools and Hand-Held Equipment (Powder Actuated Tools, Grinding Wheels)" dated 03/24/06

OS 7.4.7.5, Rev. B, "Exhaust/Ventilation Facilities" dated 05/13/05

OS 7.4.7.8, Rev. B, "Degreasers" dated 05/31/05

OS 7.4.7.10, Rev. B, "Process/Utility Facilities" dated 12/09/05

OS 7.4.7.11, Rev. A, "Welding and Brazing Safety" dated 06/01/05

OS 7.4.7.13, Rev. D, "Powered Industrial Vehicles" dated 03/24/06

OS 7.4.7.14, Rev. D, "Ladder Safety" dated 03/06/09

OS 7.4.7.17, Rev. B, "Machine Guarding" dated 07/08/05

OS 7.4.7.19, Rev. B, "Compressed Air Lines" dated 05/17/05

OS 7.4.7.20, Rev. B, "Cranes and Hoists" dated 05/26/05

CONTRACTOR EHS SYSTEMS

OM 7.4.8.1, Rev. B, "Project and Contractor Safety Systems (PACSS)" dated 04/13/04

EMPLOYEE SAFETY: NON-STANDARD TRANSPORT

OS 7.4.11, Rev. B, "Employee Safety: Non-Standard Transport" dated 09/27/05

The following is a list of the internal written Product Safety policies, operating standards and instructions that support the company's standard practices.

ENTERPRISE POLICIES AND PROCESSES

EXECUTIVE POLICIES

EP 7, Rev. B, "Product Safety" dated 07/12/04

PRODUCT SAFETY

BP 4.1.2, Rev. A, "System Safety Process" dated 02/28/05

BP 4.1.2.1, Rev. –, "Product Safety Incident Reporting" dated 02/12/04

OS 4.1.2.2, Rev. A, "Request for Early Delivery of Product Still Under Development" dated 5/19/05

REFERENCE DOCUMENTS

- Contract EHS Requirements
  - Hazardous Materials Management Overview
  - Master Hazardous Materials Management Program (HMMP) Plan
  - Subcontractor HMMP Certification and Information Request
  - HMMP Report Template and Example
- Hazard Analysis Procedures
- Hazard Identification Record
- Hazard Report Form Template
- Mishap Reporting and Investigation Procedures
- Product Liability Risk Management Process
- RF Energy Safety Assessment
- Safety Assessment Report Instructions and Template
- Safety Critical Functions Checklist
- Safety Design Guidelines Checklists
- Safety Requirements and Verification Matrix
- Software Safety Procedures
- System/Product Safety Flow Down Guidelines
- System Safety Process Kickoff Checklist
- System Safety Program Plan Template
- System Safety Working Group (SSWG) Guidelines
- Top-Level Hazards List